19141 (4-6877)

# COST MODEL

# U.S. NAVAL VESSELS (DESTROYER TYPE)

FINAL REPORT

Prepared for:

OFFICE OF NAVAL RESEARCH
CONTRACT NO. N00014-80-C-0950

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AUGUST 1981

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LIST OF ABBREVIATIONS AND DEFINITIONS

| | |
|---|---|
| B | Beam, Molded. Maximum breadth of the hull |
| BIW | Bath Iron Works |
| BSCI | Bureau of Ships Consolidated Index |
| CER | Cost Estimating Relationship |
| COMPLEMENT | Number of accommodations for officers and men on board |
| CP/FP | Controllable Pitch/Fixed Pitch Propeller |
| CUBIC NUMBER | L x $B_M$ x $D_M$/100. This represents enclosed hull volume of ship |
| DD/FF/CG | Destroyer/Frigate/Cruiser |
| D | Depth, Molded to Main Deck. (Where this factor is used to determine cubic number, since cubic number represents the ship's enclosed hull volume, the uppermost continuous deck should be used to measure depth. In some instances, this depth may not be the same as that listed in the ship's specifications (example, CG-47, DD-993) |
| G&C | Gibbs & Cox, Inc. |
| GFE | Government Furnished Equipment |
| H | Molded mean draft (also = T) |
| Habitability Standards | By year, refer to OPNAV instructions for shipboard habitability and environmental control standards for the U.S. Navy. |
| HM&E | Hull, Mechanical, and Electrical |
| KW | Installed power generating capacity in kilowatts |
| L | Length at the load waterline |
| LT | Long ton: unit of weight of 2,240 pounds or 1,016 kilos |
| MEL | Master Equipment list |
| MH | Man-hours of direct labor by shipyard employees |
| MISSILE | Refers to those missile installations that have magazine flooding requirements |
| R&D | Research and Development |
| SCN | Ship Construction, Navy |
| SHP | Shaft Horsepower |
| SWBS | Ship Work Breakdown Structure |
| TLR | Top Level Requirement |
| Wt. | Weight |

ABSTRACT

This report provides the Chief of Naval Operations, Resource Analyses Staff, OP-96D, with a method for estimating the basic acquisition cost of near-term future frigates, destroyers and cruisers of the U.S. Navy. A set of 22 cost groups, corresponding to subgroups of the seven weight groups of the Ship Work Breakdown Structure (SWBS), each having a labor and a material algorithm, can be summed to provide the basic shipyard associated costs of these ships. SWBS Groups 8 and 9, Integration/Engineering and Ship Assembly and Support Services, respectively, are also included because they are shipyard incurred costs. The result is intended to provide an independent, programming quality, basic construction cost estimate that is based upon shipyard generated cost data. This does not include the cost of GFE for the Armament Systems and Command and Surveillance Systems.

The variations among subsystems within each SWBS group, representing different subsystem characteristics, e.g., steam or gas turbine propulsion, have been addressed in those areas that seem to have significant cost variations. Corrections for the year of construction are handled by use of inflation factors for material costs. Corrections for labor figures are in the form of productivity factors, which reflect the shipyard's experience (learning curve) trends.

The minimum requirement for use of this cost model is a rough estimate of the weight and other significant variables such as shaft horsepower (SHP) or installed generating capacity in kilowatts (KW) for each of the seven SWBS one-digit weight groups. By entering each of the corresponding graphical algorithms, a development programming quality cost estimate can be obtained.

The next level of sophistication is provided by use of the 22-group cost model. In this case, the estimated weight or

other pertinent data for each of the 22 cost groups must be developed from knowledge of the three-digit SWBS elements. If some of the weights are unknown, the development of weights is assisted by (a) the historical percentage distribution among the cost groups within the weight groups, and (b) the algorithms for weight determined from the Gibbs & Cox, Inc. data base.

Upon entering the graphs of the cost model with these weights, further sophistication of the cost estimate is available if particular technical characteristics of the new ship are known. The influence of selected cost-drivers is identified by the supplementary trend lines plotted on the graphs, which are annotated to indicate the influencing characteristics.

EXECUTIVE SUMMARY

1. Introduction

This report presents a procedure to use in estimating basic construction costs for frigates, destroyers and cruisers of the U.S. Navy. It is based upon shipyard generated cost data for six ships. Bath Iron Works (BIW) was used to develop unit costs for this report. It will result in an independent, programming quality SCN basic construction cost estimate for a lead ship delivered to the Navy in 1980. Two models are presented: a one-digit cost model that utilizes weight data available at the SWBS one-digit level and a two-digit cost model that uses SWBS three-digit level weight data. Both models also require knowledge of significant characteristics of the ship's design such as SHP, KW, type of propulsion plant, and cubic number. This input can be used with either graphed or calculated algorithms to determine the material costs and labor man-hours for each cost group. These are summed to provide the basic shipyard associated cost of the lead ship, not including GFE.

2. Approach to the Cost Model Development

A significant portion of the effort involved in developing the cost model concerned the conversion of the BIW cost data into the SWBS based cost strucure for the two-digit model. The 22 two-digit groups, encompassing SWBS groups 100-700, each contain a grouping of subsystems that have similar costing characteristics. For each of these 22 groups, the shipyard reconstructed actual cost data to provide material and labor factors for six ships in the format of dollars per ton ($/ton) and man-hours per ton (MH/ton).

For each of the six ships in this study, cost drivers were identified that could impact on ship costs and perhaps result in separate algorithms within a cost group.

3. Model Description

The data for the models is in three formats: tabular lists of the non-adjusted cost factors in dollars per ton ($/ton) and man-hours per ton (MH/ton) representing actual costs at time of the ship's delivery, graphs of material costs (adjusted for inflation) and labor man-hours (adjusted for shipyard productivity) plotted against the most explanatory independent variable for that cost group and mathematical equations that reflect the same cost estimating relationships (CER) found on the graphs.

The data adjustments correct the shipyard data for the difference in the dates of construction of the ships. The BIW cost factors reflect the shipyards returned costs as of the delivery date of each ship. The material costs were adjusted for inflation from the delivery date to a 1980 standard. The labor man-hours were adjusted for the fluctuation in BIW shipyard's productivity.

The mathematical algorithms were calculated by a linear least squares regression of the data points that had similar characteristics within a cost group. The known differences between the ships accounted for many of the variations in ship costs. These formed the bases for the Cost Estimating Relationships (CER's) applications or algorithm descriptions. Where no particular application was defined for an equation, it could be used for any destroyer type vessel with characteristics similar to those costed in this model.

Costs of GFE for the Armament Systems, Command and Surveillance Systems are not included in this model, nor are the costs for training, ILS, spares, Navy Program Support and other factors leading to a total ship cost. However, the shipyard's material and labor costs for GFE installation are included in this model.

## One-Digit Level Cost Model

The one-digit level cost model will provide a cost estimate, if only the one-digit weight estimates, cubic number, KW and SHP of a ship are known. The disadvantage of this estimate is its inability to take into account features of the ship to be costed which may be different from those features included in the ships of the baseline.

At the one-digit level, SWBS groups 1 through 7 are each represented by a material CER and a labor CER. Where more than one independent variable is suggested as satisfactory for a group, cost values generated may be compared in support of each other. The algorithm applications define the scope of each CER. SWBS groups 8 and 9 costs are included but do not have weights associated with them.

The table of equations (Table 1) can be used in conjunction with the input, output and summary worksheets in Appendix E.

TABLE 1

| Group | Equation | $R^2$ | Independent Variable | Applications |
|---|---|---|---|---|
| 1 MTL | $ = 340 CN - 56,000 | .98 | Cubic Number | Aluminum Supst. HTS, HY80, MS |
| 1 MTL | $ = 1455 WT + 164,000 | .98 | GR 1 WT | Aluminum Supst. HTS, HY80, MS |
| 1 LBR | MH = 51.3 CN + 42,000 | .98 | Cubic Number | Aluminum Supst. HTS, HY80, MS |
| 1 LBR | MH = 222 WT + 70,000 | .98 | GR 1 WT | Aluminum Supst. HTS, HY80, MS |
| 2 MTL | $ = 114.4 SHP + 1,870,000 | - | SHP | Steam - Single Shaft |
| 2 MTL | $ = 114.4 SHP + 5,700,000 | .40 | SHP | Steam - Twin Shaft |
| 2 MTL | $ = 358.3 SHP | - | SHP | Geared GT - Single Shaft |
| 2 MTL | $ = 358.3 SHP + 12,736,000 | - | SHP | Geared GT - Twin Shaft |
| 2 MTL | $ = 358.3 SHP + 12,338,000 | - | SHP | Electric GT - Single Shaft |
| 2 MTL | $ = 358.3 SHP + 19,219,000 | - | SHP | Electric GT - Twin Shaft |
| 2 LBR | MH = 3.11 SHP - 2,700 | .97 | SHP | Steam |
| 2 LBR | MH = 3.11 SHP - 29,000 | - | SHP | Geared Gas Turbine |
| 2 LBR | MH = 3.14 SHP + 31,700 | - | SHP | Electric Gas Turbine |
| 3 MTL | $ = 487 KW + 2,391,000 | .84 | KW | Steam Generators |
| 3 MTL | $ = 282 KW + 1,382,000 | - | KW | Steam & Diesel Generators |
| 3 MTL | $ = 716 KW + 3,485,000 | - | KW | Diesel Generators (for GT) |
| 3 LBR | MH = 1,096 WT - 7,100 | .98 | GR 3 WT | Steam Generators |
| 3 LBR | MH = 879 WT - 6,000 | - | GR 3 WT | Diesel Generators (for GT) |
| 4 MTL | $ = 1440 WT + 1,029,000 | .81 | GR 4 WT | Early Technology |
| 4 MTL | $ = 5330 WT + 1,920,000 | - | GR 4 WT | Current Technology |
| 4 LBR | MH = 513 WT + 34,700 | .97 | GR 4 WT | |
| 5 MTL | $ = 6,760 WT + 1,023,000 | .90 | GR 5 WT | Steam Heat - "Non-Missile" |
| 5 MTL | $ = 17,200 WT + 2,604,000 | - | GR 5 WT | Electric Heat - "Missile" |
| 5 LBR | MH = 1,150 WT - 59,400 | .94 | GR 5 WT | Steam Heat - "Non-Missile" |
| 5 LBR | MH = 780 WT - 40,300 | - | GR 5 WT | Electric Heat - "Missile" |
| 6 MTL | $ = 84.6 (LxB) + 46,000 | .97 | Length x Beam | Pre-1965 Habitability |
| 6 MTL | $ = 151.3 (LxB) + 302,000 | - | Length x Beam | Post-1965 Habitability |
| 6 MTL | $ = 4,850 WT + 462,000 | .90 | GR 6 WT | Pre-1965 Habitability |
| 6 MTL | $ = 7,380 WT + 777,000 | - | GR 6 WT | Post-1965 Habitability |
| 6 LBR | MH = 20.7 (LxB) - 88,000 | .98 | Length x Beam | Pre-1965 Habitability |
| 6 LBR | MH = 22.2 (LxB) - 88,000 | - | Length x Beam | Post-1965 Habitability |

TABLE 1 (Continued)

| Group | Equation | $R^2$ | Independent Variable | Applications |
|---|---|---|---|---|
| 7 MTL | \$ = 1,970 WT - 293,000 | .96 | GR 7 WT | Early Technology |
| 7 MTL | \$ = 7,320 WT + 350,000 | - | GR 7 WT | Current Technology |
| 7 LBR | MH = 492 WT - 24,400 | .91 | GR 7 WT | |
| 8 MTL | \$ = 995,000 | | | |
| 8 LBR | MH = 790,000 | | | |
| 9 MTL | \$ = 45,500 x Months | - | Months Construction | |
| 9 LBR | MH = 16,000 x Months | - | Months Construction | |

## Two-Digit Level Cost Model

The two-digit level model consists of 22 cost groups, each of which is represented by at least one material cost CER and a labor man-hours CER (Table 2). SWBS Groups 8 and 9 costs are included in the total ship cost, although they do not have weights associated with them.

Where supplementary algorithms are specified, the relationship most applicable to the system being costed should be used.

The table of equations (Table 3) can be used in conjunction with the input, output, and summary worksheets in Appendix E.

Table 2 Two-Digit Cost Model Structure

| Cost Group | Group Title | Group | Group Title |
|---|---|---|---|
| 1A | Structural Envelope/ Subdivisions | 5A | Environment System |
| | | 5B | Fluid System |
| 1B | Superstructure | 5C | Maneuvering System |
| 1C | Foundations | 5D | Equipment Handling System |
| 1D | Structural Attachments | | |
| 2A | Propulsion Energy System | 6A | Hull Fittings |
| 2B | Propulsion Train System | 6B | Non-Structural Subdivisions |
| 2C | Propulsion Gases (Intake and Exhaust) System | 6C | Preservation |
| 2D | Propulsion Service System | 6D | Facilities |
| | | 6E | Habitability |
| 3A | Electrical Power Generation | 7 | Ordnance |
| 3B | Electrical Power Distribution | | |
| 4A | Vehicle Command | 8 | Design and Engineering Services |
| 4B | Weapon Command | 9 | Construction Services |

TABLE 3

| Group | Equation | $R^2$ | Independent Variable | Applications |
|---|---|---|---|---|
| 1A MTL | \$ = 258 CN - 687,000 | .97 | Cubic Number | HY80-HTS-MS |
| 1A MTL | \$ = 1,304 WT - 411,000 | .96 | GR 1A WT | HY80-HTS-MS |
| 1A LBR | MH = 28.8 CN + 68,600 | .99 | Cubic Number | HY80-HTS-MS |
| 1A LBR | MH = 146 WT + 98,600 | .98 | GR 1A WT | HY80-HTS-MS |
| 1B MTL | \$ = 4,020 WT + 5,000 | .85 | GR 1B WT | Aluminum Superstructure |
| 1B MTL | \$ = 850 WT | - | GR 1B WT | Steel Superstructure |
| 1B LBR | MH = 449 WT + 1,000 | .97 | GR 1B WT | Aluminum Superstructure |
| 1B LBR | MH = 300 WT | - | GR 1B WT | Steel Superstructure |
| 1C MTL | \$ = 1,120 WT + 1,000 | .70 | GR 1C WT | Steam |
| 1C MTL | \$ = 1,760 WT - 5,000 | - | GR 1C WT | Gas Turbine |
| 1C LBR | MH = 1,000 WT - 67,800 | .94 | GR 1C WT | Steam Plant |
| 1C LBR | MH = 633 WT - 45,000 | - | GR 1C WT | Gas Turbine Plant |
| 1D MTL | \$ = 1,540 WT + 571,000 | .78 | GR 1D WT | "Bought" |
| 1D LBR | MH = 484 WT - 14,600 | .96 | GR 1D WT | "Bought" |
| 2A MTL | \$ = 156 SHP - 446,000 | .91 | SHP | Steam |
| 2A MTL | \$ = 178 SHP + 214,000 | - | SHP | Geared Gas Turbine |
| 2A MTL | \$ = 208.3 SHP + 16,199,000 | - | SHP | Electric Gas Turbine - Twin |
| 2A LBR | MH = 1.92 SHP - 18,700 | .97 | SHP | Steam |
| 2A LBR | MH = 1.30 SHP + 300 | - | SHP | Geared Gas Turbine |
| 2A LBR | MH = 1.98 SHP + 25,300 | - | SHP | Electric Gas Turbine |
| 2B MTL | \$ = 11.9 SHP + 112,000 | .97 | SHP | Fixed Pitch |
| 2B MTL | \$ = 46 SHP + 433,000 | - | SHP | Controllable Pitch |
| 2B LBR | MH = 0.36 SHP + 6,500 | .83<br>- | SHP | |
| 2C MTL | \$ = 20.7 SHP - 592,000 | .91 | SHP | Steam |
| 2C MTL | \$ = 48.2 SHP - 1,378,000 | - | SHP | Gas Turbine |
| 2C LBR | MH = 0.61 SHP - 13,600 | .92 | SHP | |
| 2D MTL | \$ = 10.4 SHP + 148,000 | .89 | SHP | Steam |
| 2D MTL | \$ = 76.9 SHP + 1,093,000 | - | SHP | Gas Turbine |
| 2D LBR | MH = 543 WT - 5,400 | .97 | GR 2D WT | |

TABLE 3 (Continued)

| Group | Equation | $R^2$ | Independent Variable | Applications |
|---|---|---|---|---|
| 3A MTL | \$ = 121 KW + 1,909,000 | .88 | KW | Steam Generators |
| 3A MTL | \$ = 65.8 KW + 1,027,000 | - | KW | Steam & Diesel Generato |
| 3A MTL | \$ = 183 KW + 2,888,000 | - | KW | Diesel (for GT customiz |
| 3A LBR | MH = 200 WT + 1,600 | .95 | GR 3A WT | |
| 3B MTL | \$ = 29,200 WT - 583,000 | .90 | GR 3B WT | |
| 3B LBR | MH = 1,780 WT - 4,000 | .91 | GR 3B WT | |
| 4A MTL | \$ = 3,830 WT + 591,000 | .82 | GR 4A WT | Early Technology |
| 4A MTL | \$ = 6,180 WT + 997,000 | - | GR 4A WT | Current Technology |
| 4A LBR | MH = 1,010 WT - 8,700 | .98 | GR 4A WT | |
| 4B MTL | \$ = 1,740 WT + 194,000 | .99 | GR 4B WT | Early Technology |
| 4B MTL | \$ = 6,910 WT + 768,000 | - | GR 4B WT | Current Technology |
| 4B LBR | MH = 416 WT + 34,300 | .90 | GR 4B WT | |
| 5A MTL | \$ = 9,060 WT + 64,000 | .94 | GR 5A WT | Steam Heat |
| 5A MTL | \$ = 18,900 WT + 152,000 | - | GR 5A WT | Electric Heat |
| 5A LBR | MH = 1,430 WT + 27,600 | .89 | GR 5A WT | Steam Heat |
| 5A LBR | MH = 938 WT + 14,500 | - | GR 5A WT | Electric Heat |
| 5B MTL | \$ = 7,540 WT + 589,000 | .95 | GR 5B WT | Steam - "Non-Missile" |
| 5B MTL | \$ = 20,700 WT + 1,784,000 | - | GR 5B WT | Gas Turbine - "Missile" |
| 5B LBR | MH = 1,150 WT - 32,000 | .99 | GR 5B WT | Steam - "Non-Missile" |
| 5B LBR | MH = 796 WT - 19,300 | - | GR 5B WT | Gas Turbine - "Missile" |
| 5C MTL | \$ = 3,730 (LxH/100) + 56,000 | .80 | LxH/100 | |
| 5C LBR | MH = 174 (LxH/100) - 3,000 | .91 | LxH/100 | |
| 5D MTL | \$ = 9,000 WT | - | GR 5D WT | |
| | -to- | | | |
| | \$ = 12,000 WT | - | | |
| 5D LBR | MH = 200 WT | - | GR 5D WT | |
| | -to- | | | |
| | MH = 300 WT | - | | |

TABLE 3 (Continued)

| Group | Equation | $R^2$ | Independent Variable | Applications |
|---|---|---|---|---|
| 6A MTL | $ = 11 (LxB) + 42,000 | .78 | LxB | Early Technology |
| 6A MTL | $ = 18 (LxB) + 102,000 | - | LxB | Current Technology |
| 6A LBR | MH = 718 WT - 1,300 | .96 | GR 6A WT | |
| 6B MTL | $ = 8.42 (LxD) + 104,000 | .93 | LxD | Pre-1965 Habitability |
| 6B MTL | $ = 24.2 (LxD) + 272,000 | - | LxD | Post-1965 Habitability |
| 6B MTL | $ = 2,260 WT + 119,000 | .94 | GR 6B WT | Pre-1965 Habitability |
| 6B MTL | $ = 4,830 WT + 266,000 | - | GR 6B WT | Post-1965 Habitability |
| 6B LBR | MH = 1,210 WT + 2,600 | .93 | GR 6B WT | |
| 6C MTL | $ = 38.9 (LxB) - 297,000 | .98 | | Early Technology |
| 6C MTL | $ = 53.5 (LxB) - 398,000 | - | LxB | Current Technology |
| 6C LBR | MH = 14.4 (LxB) - 128,600 | .97 | LxB | |
| 6D MTL | $ = 238 COMP + 159,000 | .85 | Complement | Pre-1965 Habitability |
| 6D MTL | $ = 489 COMP + 328,000 | - | Complement | Post-1965 Habitability |
| 6D LBR | MH = 876 WT + 9,700 | .93 | GR 6D WT | Pre-1965 Habitability |
| 6D LBR | MH = 553 WT + 5,300 | - | GR 6D WT | Post-1965 Habitability |
| 6E MTL | $ = 7,130 WT + 250,000 | .90 | GR 6E WT | Pre-1965 Habitability |
| 6E MTL | $ = 11,900 WT + 444,000 | - | GR 6E WT | Post-1965 Habitability |
| 6E LBR | MH = 407 WT + 15,200 | .87 | GR 6E WT | |

## 4. Conclusions

The costs generated by this model are based upon a fixed range of U.S. frigates, destroyers and cruisers. For larger vessels that have the same basic characteristics as those described in this model, but which would require extensions of the graphs, the mathematical equations may be used to estimate group costs. (Confidence in the accuracy of the algorithm will decrease with increasing extrapolation.)

Where possible, the two-digit model should be used to determine basic construction costs since it is more sensitive to variations in characteristics of the ship.

In terms of significant figures, the algorithms are recorded in terms of the results of the linear regression analysis modified to reflect three significant figures in most instances.

For ships of the general type considered by this model, a cost estimate of programming quality can be produced.

# 1. INTRODUCTION

The objective of this effort is to develop a cost model for U.S. destroyer type ships based upon actual shipyard return cost data. It will provide the Chief of Naval Operations, Resources Analyses Staff, OP-96D, with an independent cost analysis capability for general force planning, allocation of resources, and other significant purposes in today's cost constrained environment. The model will provide accurate repeatable results that can be relied upon to validate estimates received from other sources or to form a base for internal estimating purposes.

The goal is to provide feasibility level estimates (Reference 1) for near-future (1980's) vessels. The scope is limited to shipyard costs only (Reference 2) and does not include the acquisition of government-furnished equipment (GFE) with respect to command, control, communications and weapons systems, or additional costs such as training, ILS, spares or Navy program support. The model is designed to utilize information available at the end of the feasibility stage, including such items as the three-digit weight breakdown, shaft horsepower, kilowatts, and cubic number.

The shipbuilding firm of Bath Iron Works (BIW) has a long history of building the types of vessels used in this model, with Gibbs & Cox, Inc. as their design agent. In addition, a number of experienced cost estimators were available for this effort. Their knowledge of the BIW data was invaluable in transforming shipyard costs into the Navy format for this model.

The U.S. Navy has subdivided the work of shipbuilding into the nine groups, shown in Table 1.1. The Ship Work Breakdown Structure (SWBS) system, which keeps track of ship specifications, weights, costs, drawings, and reports, was first known as the Bureau of Ships Consolidated Index (BSCI) system.

The value of such a structure lies in its familiarity (which is built up by learning and refining through constant use), its acceptance as a standard (which is acquired through regulated adherence), and its definition (through the associated data base, which is accumulated over time).

Table 1.1 - U.S. Navy Shipbuilding Subdivisions/
SWBS One-Digit Groups

| No. | Description | Weight | Cost |
|---|---|---|---|
| 1 | Hull Structure | X | X |
| 2 | Propulsion Plant | X | X |
| 3 | Electric Plant | X | X |
| 4 | Command and Surveillance | X | X |
| 5 | Auxiliary Systems | X | X |
| 6 | Outfit and Furnishings | X | X |
| 7 | Armament | X | X |
| 8 | Integration/Engineering | | X |
| 9 | Ship Assembly & Support Svcs. | | X |

It would be impractical to consider a different primary ship breakdown structure since this system is familiar to both the U.S. Navy and the shipbuilding industry. However, below this one- digit level, the practicality of further subdivision depends upon the adherence, understanding and cooperation of people who are or should be using the structure. Although the model must be used in conjunction with SWBS data, it was hoped that it would be independent of the Navy cost estimating data base. A modified cost structure was developed after recognizing that shipyard data was not accumulated by means of the U.S. Navy structure, requiring that some judgment be made to translate from one data base to another.

# 2. APPROACH TO THE COST MODEL DEVELOPMENT

To assure a comprehensive analysis of all aspects of the cost model development process, an extensive data search was conducted. The Gibbs & Cox data base provided many of the documents, while other information was gathered from discussions held with OP 96D, BIW, and Gibbs & Cox staff.

## 2.1 Cost Data

A major problem in collecting cost data from any shipyard is the requirement to translate that data into a form recognizable to the user. Cost data is recorded at the shipyard for a number of reasons, but not specifically for the purpose of accommodating the U.S. Navy's cost estimating process. In fact, the NAVSEA Ship Work Breakdown Structure (SWBS) System, which was developed in 1973 to replace the 20-year old Bureau of Ships Consolidated Index (BSCI), was proposed by the Navy for adoption by shipyards working with the Navy (References 3 and 4). That goal has not been attained, which has caused difficulty in the conversion of shipyard records to the Navy structure. A significant portion of the effort involved in developing this cost model concerned the conversion of the BIW cost data into the SWBS based cost structure shown in Table 2.1.

This structure, which has been defined for the purposes of this model as a two-digit breakdown, groups ship subsystems (as defined by the SWBS three-digit breakdown) that exhibit cost characteristics similar to the groups shown. This allocation is based on the familiarity of the BIW estimators and the Gibbs & Cox, Inc. engineers with the subsystems of interest, as verified by the BIW cost data. Each of the two-digit groups has a different character with respect to the value of the cost factors used in estimating costs. The 22 groups encompass Groups 100 through 700 of the three-digit SWBS groups.

Table 2.1 Two-Digit Cost Model Structure

| Cost Group | Group Title | Group | Group Title |
|---|---|---|---|
| 1A | Structural Envelope/ Subdivisions | 5A | Environment System |
| | | 5B | Fluid System |
| 1B | Superstructure | 5C | Maneuvering System |
| 1C | Foundations | 5D | Equipment Handling System |
| 1D | Structural Attachments | | |
| 2A | Propulsion Energy System | 6A | Hull Fittings |
| 2B | Propulsion Train System | 6B | Non-Structural Subdivisions |
| 2C | Propulsion Gases (Intake and Exhaust) System | 6C | Preservation |
| 2D | Propulsion Service System | 6D | Facilities |
| | | 6E | Habitability |
| 3A | Electrical Power Generation | 7 | Ordnance |
| 3B | Electrical Power Distribution | | |
| 4A | Vehicle Command | 8 | Design and Engineering Services |
| 4B | Weapon Command | | |
| | | 9 | Construction Services |

The definition of each cost group lies in the equipment content of the assigned weight groups. Each cost group has been given a one- or two-word title to approximate its contents, but these titles are applicable only to this model and are not associated with any other cost structure or system. At this two-digit level, each cost group is represented by a material factor and a labor factor.

Table 2.2 lists the independent variables that were used for each cost group to relate costs to the technical characteristics of the ships. The cost estimating relationships that were developed break down the BIW data of material costs ($/ton) and labor costs (MH/ton) into usable algorithms that graph material costs ($) or labor man-hours (MH) against the most explanatory variable for that group. Those parameters selected for use in this model are graphed in Section 3.4 for six baseline ships (FFG-7, FFG-4, CG-26, CG-16, DDG-2, DD-931). The other graphs, which were rejected as not sufficiently representative of cost trends, are included in Appendix F for information only.

The SWBS groups that do not address actual ship systems are Groups 0 (General Guidance and Administration), 8 (Integration/Engineering) and 9 (Ship Assembly and Support Services); they do, however, entail cost (Reference 3). The costs associated with Group 0 include the development of requirements to be addressed by Groups 1 through 9. Those costs are not included in this model, since they are not incurred by the shipyard. Group 8 and 9 costs are included, since they are associated with the fabrication of the ship, and are discussed in Section 3.5, Software.

In any ship design, the spiral of development (Reference 6) begins with the selection of a tentative payload. On ship types analyzed for this model, the combat system is considered the payload, which cannot be expected to follow the explicit trend lines as other dependent subsystems do. Barring

TABLE 2.2
INDEPENDENT VARIABLES

| Cost Group | Cost Group Title | Material | Labor |
|---|---|---|---|
| 1A | Structural Envelope/Subdiv. | CN/WT | CN/WT |
| 1B | Superstructure | WT | WT |
| 1C | Foundations | WT | WT |
| 1D | Structural Attachments | WT | WT |
| Total | WEIGHT GROUP 1 | CN/WT | CN/WT |
| 2A | Propulsion Energy System | SHP | SHP |
| 2B | Propulsion Train System | SHP | SHP |
| 2C | Propulsion Gases System | SHP | SHP |
| 2D | Propulsion Service System | SHP | LT |
| Total | WEIGHT GROUP 2 | SHP | SHP |
| 3A | Elec. Power Generation | L | L |
| 3B | Elec. Power Distribution | WT | WT |
| Total | WEIGHT GROUP 3 | L/KW | L |
| 4A | Vehicle Command | WT | WT |
| 4B | Weapon Command | WT | WT |
| Total | WEIGHT GROUP 4 | WT | WT |
| 5A | Environment System | CN/WT | WT |
| 5B | Non-Struct. Subdiv. | WT | WT |
| 5C | Maneuvering System | LxH/100 | LxH/100 |
| 5D | Handling System | WT | WT |
| Total | WEIGHT GROUP 5 | CN | CN |
| 6A | Hull Fittings | COMPL | LxB |
| 6B | Non-Struct. Subdiv. | WT/LxD | COMPL |
| 6C | Preservation | LxB | LxB |
| 6D | Facilities | COMPL | WT |
| 6E | Habitability | WT | COMPL |
| Total | WEIGHT GROUP 6 | LxB/WT | LxB |
| 7 | Ordnance Handling & Launch | | |
| Total | WEIGHT GROUP 7 | WT | WT |

Key:
L - Length
B - Beam
D - Depth
H = Draft
CN = Cubic Number

WT = Group Weight
KW = Kilowatts
SHP = Shaft Horsepower
COMPL = Complement

radical selections of payloads, the present day U.S. Navy does maintain a gross trend in weapon suites' weights, but their costs depend mainly upon their performance and sophistication, which are not measured as easily as weight, space, etc. The main reason for treating Groups 4 and 7 differently is the custom of providing these systems as Government Furnished Equipment (GFE), which reduces shipyard involvement with acquisition and, subsequently, reduces knowledge of their costs.

## 2.2 Weight Data

When costing ships for feasibility studies, individual subsystems (and the actual equipment) may not yet be defined; instead, only the function that will require such a subsystem may be identified. Normally, the functional requirements of existing similar ships will be sufficient for this model, even if the installed subsystem supplying the operational capability has changed over the years due to technology or more stringent requirements.

It was not possible to ascribe a specific cost to each piece of equipment or subsystem installed for the following reasons:

- The recordkeeping procedures of the individual shipyards
- The level of complexity that would develop in the model

Consequently, it was necessary to represent these components by some measurable substitute. Space, weight, and power requirements proved to be good parameters due to their availability. Over the years, the ship engineering community has built up a data base for ship design and construction using these parameters. The data bases at Gibbs & Cox and at BIW were tapped for these measurements.

In particular, three-digit SWBS weights (Reference 6) were sought for the six ships in the BIW data base. The most detailed and accurate weights available for several ships (Destroyer Weight Analysis, Reference 7) were still in the form of the BSCI system, since all destroyer/cruiser type ships except the FFG-7 and DD-963 have been designed and built using the BSCI breakdown. An attempt was made to convert to the SWBS system, which could only be approximated in some instances. Weight estimates range from early preliminary design estimates through detailed estimates and weight reports containing returned weights that are either calculated or actually weighed.

The result was acceptance of the BSCI weight distribution among the two-digit cost groups, which has been detailed in Appendix B in terms of the corresponding three-digit SWBS titles. Since we know which three-digit SWBS groups are in each two-digit cost group, the user can enter the model with SWBS information. Appendix C details the minor discrepancies in the BSCI to SWBS conversion and explains their impact on the cost model.

The weight associated with each group for which cost is desired represents the set of installed equipment/components that provide some function(s) for the ship system. The basic weight algorithm for each group (Appendix B) can be used to determine that weight. Weight as a parameter provides one convenient measurable quantity to relate to the area that is to be costed.

Ships can have the same weight in one area, yet have different costs due to any of a number of factors. Alternately, they can have different weights with similar costs. The important points are first, that other parameters may present different pictures of the cost relationships, and, second, that the objective of the algorithm approach is to generalize cost trends from a set of specific cases in order to provide insight in costing future ships.

## 2.3 Ship Data

The candidate ships for examination in this task are listed in Table 2.3. The sources referenced provided much of the

Table 2.3 Cost Analysis Reference Points

| | Commission Date | DD Weight Analysis (Ref 7) | Major Drivers (Ref 10) | MIDMIX Study (Ref 6) | Soviet Study (Ref 11) |
|---|---|---|---|---|---|
| 1. DDGX | (1987) | | | | |
| 2. CG-47 | (1983) | | X | | |
| 3. DDG-993 | (1981) | | | | |
| 4. FFG-7* | 1977 | X | X | X | X |
| 5. DD-963 | 1975 | X | X | X | |
| 6. FF-1052 | 1969 | X | X | X | |
| 7. FFG-4* | 1967 | | | | X |
| 18. FF-1040 | 1964 | X | X | X | |
| 19. CG-26* | 1964 | X | X | X | |
| 10. CG-16* | 1962 | X | X | | |
| 11. DDG-40* | 1960 | X | | | |
| 12. DDG-2* | 1960 | X | X | | X |
| 13. DD-931* | 1955 | X | X | | X |

Note: FFG-4 represents the FFG-1 class because it is the first ship of this class that BIW built.

data on the weights and technical features. These candidates were selected from the U.S. Navy classification of combatant ships (excluding nuclear types) within the time frame of 1955 to the present. One constraint was the availability of shipyard costs (several additional shipyards were considered, but resources were not available for acquiring their data). BIW has built those types indicated by an asterisk (*).

The newer ships on the list will be prime test cases for this model when their return cost data becomes available. They will be able not only to test the model, but to confirm algorithms for the gas turbine example.

The costs for DD-963 were not available for this study. Had they been available, however, they would not have easily been compared to those for the other ships. The 30-ship buy commencing with the 1975 delivery of the lead ship, DD-963, was acquired under a form of contract that spread the lead ship costs over the 30 ships and that included many subsystems normally thought of as GFE.

Cost data for the FF-1052 and FF-1040 were sought from another shipyard, which would also be a second source for DDG-2 data to confirm the BIW data. The FF-1040 would also have confirmed the BIW data on the FFG-4 since the ships are identical except for a change in the weapon system. The proposed second source decided that the effort would entail disclosures of proprietary information (which would have been too costly to sanitize).

Although built at BIW, the DDG-40 class no longer had a data base available for this study, due to the policy of destroying "old" data. The data available at BIW in terms of return costs, therefore, limited the samples for this model to the six ship types shown in Table 2.4. Sixty of these ships were

TABLE 2.4
CHARACTERISTICS OF SAMPLE SHIPS

| PARAMETER | DD 931 | DDG 2 | CG 16 | CG 26 | FFG 4 | FFG 7 |
|---|---|---|---|---|---|---|
| Number Ships Built | 14 | 23 | 9 | 9 | 6 | 8[1] |
| Year Commissioned | 1955-59 | 1960-64 | 1962-64 | 1964-67 | 1966-67 | 1977-80 |
| BIW Delivery Date | 11/55 | 8/60 | 7/62 | 11/64 | 4/67 | 11/77 |
| Displacement, Full | 3960 | 4500 | 7800 | 7900 | 3426 | 3605 |
| Length Between Perpendiculars | 407 | 420 | 510 | 524 | 414 | 408 |
| Beam | 45 | 47 | 54.9 | 54.8 | 44.2 | 45 |
| Draft | 23 | 20 | 24.8 | 28.8 | 24.2 | 24.5 |
| Depth on Center Line | 29.0 | 28.7 | 38.9 | 39.0 | 31.6 | 31.7 |
| Cubic Number | 5217 | 5669 | 10619 | 11031 | 5420 | 5848 |
| Volume | 414,484 | 488,492 | 823,299 | 867,776 | 406,949 | 531,980 |
| Complement | 337 | 355 | 395 | 418 | 251 | 185 |
| Power Plant | 2 Geared Steam Turbines | 2 Geared Steam Turbines | 2 Geared Steam Turbines | 2 Geared Steam Turbines | 1 Geared Steam Turbine | 2 Gas Turbines |
| SHP | 70,000 | 70,000 | 85,000 | 85,000 | 35,000 | 41,000 |
| KW | 2,400 | 2,400 | 4,600 | 6,600 | 3,000 | 4,000 |
| Shafts/Propellers | 2/FP | 2/FP | 2/FP | 2/FP | 1/FP | 1/CP |
| Other | 4 Boilers | 4 Boilers | 4 Boilers | 4 Boilers | 2 Boilers | 4 Diesel Generators |

Note:
1. A total of 31 ships have been assigned to building yards for commissioning through 1984.

built between 1955 and 1967 (22 by BIW). Another 30 ships will be built between 1977 and 1984.

The characteristics of those ships not in the cost baseline are given in Table 2.5, and their weight distributions are listed in Appendix A.

Another sophistication that was tried unsuccessfully was to obtain the Master Equipment List (MEL) and Top Level Requirement (TLR) for these ships (References 8 and 9). The goal of recognizing the differences between ships in terms of variations in installed equipment performance capability, which imply cost differences even if weights are not greatly affected, was considered attractive. However, this goal was frustrated by a lack of data in the appropriate forms and the amount of effort required to properly interpret the data. It is believed that the inability to incorporate this subtlety does not detract from the accuracy of the model, since such accuracy is beyond the scope of the data base that will be available for a Class "D" cost estimate.

The adopted equipment lists (Ship Subsystem Cost Drivers, Appendix D) for those ships that are included in the analyses of weights, costs or performance, have provided a basis for relating costs to differences in weight or performance of the analyzed ships. Relative (rather than absolute) costs for variations from normal equipment can be used to further modify group/system costs obtained from algorithms.

Existing weight analyses by BSCI or SWBS groups, such as those found in References (7), (10), and (11), were reviewed for observed differences between sample ship cases. Reasons for differences were used to adjust weight algorithms and they became potential factors for fine tuning or explaining cost variations with respect to basic cost algorithms.

## TABLE 2.5
## CHARACTERISTICS OF OTHER SHIPS

| PARAMETER | DDG-40 | FF-1052 | DD-963 | DDG-993 | CG-47 | DDGX |
|---|---|---|---|---|---|---|
| Number Ships Built | 10 | 46 | 26 (+5) | 4 | 2 | ( )[1] |
| Year Commissioned | 1959-61 | 1969-74 | 1975-(83) | 1980-81 | (1983-?) | |
| BIW Delivery Date | 1960 | | | | | |
| Displacement, Full | 5709-5907 | 3877 | 7810 | 8300 | 9055 | 8130 |
| Length Between Perpendiculars | 490 | 415 | 529 | 529 | 529 | 480 |
| Beam | 52 | 46.8 | 55 | 55 | 55 | 60 |
| Draft | 23.4 | 24.8 | 19.6 | 20.6 | 21.6 | 19 |
| Depth on Center Line | 30.75 | 30.85 | 33 | 33 | 33 | 33 |
| Cubic Number | 7835 | 5992 | 9620 | 9620 | 9620 | 9500 |
| Volume | | | | | | |
| Complement | 373 | 245 | 296 | 338 | 316 | 323 |
| Power Plant | 2 Geared Steam Turbines | 1 Geared Steam Turbine | 4 Gas Turbines | 4 Gas Turbines | 4 Gas Turbines | 4 Gas Turbines |
| SHP | 85,000 | 35,000 | 80,000 | 80,000 | 80,000 | 75,000 |
| KW | --- | --- | --- | --- | --- | --- |
| Shafts/Propellers | 2/- | 1/FP | 2/CP | 2/CP | 1/CP | 2/CP |
| Other | 4 Boilers | Non-Press. Boilers | 3 Gas Tur Gen. | 3 Gas Tur Gen. | 3 Gas Tur Gen. | 3 Gas Tur Gen. |

NOTE:
1. Characteristics are still evolving. This data represents only one version.

The basic algorithms developed can only be used to predict costs if the new ships have systems similar to those in past ships. Appendix D, Ship System Cost Drivers, contains a listing of possible variations of systems within each of the cost groups identified for this model.

These potential cost drivers were identified for the sample ships where applicable. Also included were all possible variations that could be applicable to near future ships as determined by Gibbs & Cox, Inc. The Subsystem Cost Drivers List (Appendix D) served as the foundation for the BIW analysis of cost drivers among the shipboard systems of interest. All the variations included in the table were evaluated by BIW to determine whether or not unique cost factors would be required. As expected, most of the cost factor differences were minor and well below the expected sensitivity of the model.

The cost implications of these technical features appear in the one-digit and two-digit cost models, wherever sufficient cost data was available to measure the distinction. Each variation represents a difference in technology that could impact on costs and ultimately result in separate trend lines for a given cost group. The description of these trend lines/ algorithms appears in Section 3.4.

# 3. MODEL DESCRIPTION

The cost model that has been developed here is innovative, but does have features similar to other models that have been used before. The unique aspects and fine points discussed below distinguish this model from others and are intended to alert the user to its attributes and applications.

## 3.1 Prior Models

Older models used by OPNAV and NAVSEA for costing ships, such as the RAND model and the NAVSHIPS model (References 12 and 13), were built around the seven weight groups of the BSCI and SWBS systems and include additional cost considerations not associated with weights (e.g., Groups 8 and 9). A Study of Ship Acquisition Cost Estimating in the Naval Sea Systems Command (Reference 2) describes the NAVSEA ship costing process and defines the basic construction costs developed in each of the older models to include labor, materials, overhead, and profit. Reference (2) also reviews the costs that these older models exclude, such as Research, Development, Test and Evaluation (RDT&E), and others defined in Table 3.1, the Breakdown of the Ship Construction, Navy (SCN) Estimate.

This model and the older models develop basic construction costs. These basic construction costs include man-hours for labor, material costs, and the shipyard's costs for design, engineering, and construction services.

Table 3.1. Breakdown of SCN Estimate

| | |
|---|---|
| Plan Cost | Ordnance |
| Basic Construction/Conversion* | Future Character Changes |
| Change Orders | Escalation Budgeted |
| Electronics | Escalation Earned |
| Propulsion Equipment | Project Managers |
| Hull, Mechanical, Electrical | Growth Factor |
| Other Costs | Total Ship Estimate |

This model uses a two-digit level breakdown, while the NAVSEA model uses three-digit SWBS groups. The NAVSEA model's data points are based upon contractor "bids". The Gibbs & Cox model is based upon actual returned costs for six ships.

To illustrate the effect of variability associated with sample ships, Figure 3.1 (taken from "NAVSHIPS" data) shows the DDG-2 one-digit cost factors (1965 $) displayed against the cost factors from other destroyer type ships of similar total light ship displacement. The BIW data for DDG-2 is also plotted for comparison.

The confidence indicated by the close match of the NAVSEA model and the BIW data for one ship is countered by the realization that similar ships vary significantly in cost. The choice of sample ships will have a significant effect on the conclusions of the model.

The independent variables used to determine costs are similar in all of these models, but are handled a little differently in various cost groups. A critique of cost models (Reference 14) explores the logic and value of selection of such parameters. It also addresses the issue of using returned costs as opposed to contractor bids.

Cost groups and parameters in the Gibbs & Cox model are based on the cost characteristics of the selected subsystems under consideration. The characteristics of the 22 cost groups (two-digit level cost model) are more specifically related to weight, volume, or power than are the more general seven cost groups (one-digit level cost model), which is one advantage of the use of cost groups below the one-digit SWBS level.

# DESTROYER TYPES WITH LIGHT SHIP WEIGHT SIMILAR TO DDG-2

SOURCE: Ref. 13

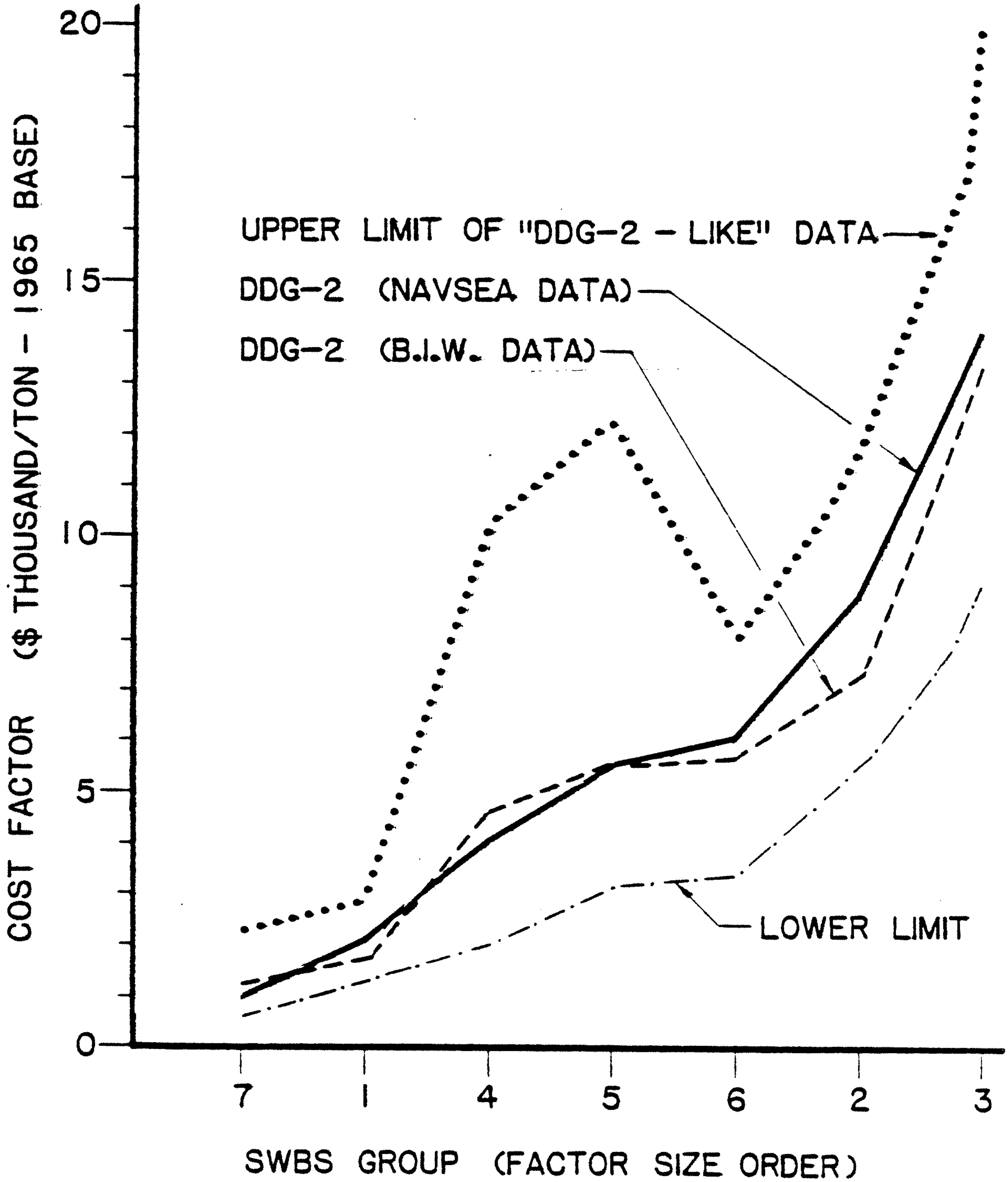



FIGURE 3.1

## 3.2 Cost Factors

The attention given to each cost group was influenced by a similar cost study that focused on Soviet combatants (Reference 11). Cost group percentages of the basic construction cost, as shown in Table 3.2, indicate the importance of each cost group to the total ship's cost. The top ten cost groups account for 75 percent of the cost of weight Groups 1 through 7. Appendix A indicates that the same cost groups also account for 75 percent of the weight. The implications of this observation are that a high degree of error in a cost group that contributes less than 3 percent of the cost is not too damaging to the overall estimate, and that the time spent on refining algorithms is best used in the most significant cost areas.

Cost factors for the six baseline ships are contained in Tables 3.3 and 3.4. (Cost factors are in the form $/ton or MH/ton as of the delivery date of each ship.) Corresponding weights at the two-digit level are included in Table 3.5. The product of the weight and the associated factors gives the actual material and labor cost recorded by BIW as of the delivery date of the ship.

Material Cost ($) = Material Factor ($/ton) x Group Weight (tons)

Material costs include those materials purchased by the shipyard, such as steel, motors, generators, winches, pumps, lifeboats, and galley equipment. Some materials are purchased from manufacturers ready to install upon the ship, while others, like the hull steel, require considerable labor to fabricate or assemble. Materials not used for the ship itself, but necessary for the functioning of the shipyard (e.g., temporary utilities and services, contract administration, etc.), are included under software costs (Section 3.5).

Labor Man-hours (MH) = Labor Factor (MH/ton) x Group Weight (tons)

Labor costs include the man-hours involved in the construction and assemblage of raw materials and in the installation of equipment.

## TABLE 3.2
## APPROXIMATE PERCENTAGE OF BASIC SHIP CONSTRUCTION COST

| Cost Group | DD-931 | DDG-2 | CG-16 | CG-26 | FFG-4 | FFG-7 |
|---|---|---|---|---|---|---|
| 1A | 11% | 12% | 12% | 13% | 13% | 9% |
| B | 3% | 3% | 2% | 2% | 2% | 2% |
| C | 2% | 2% | 3% | 3% | 2% | 2% |
| D | 2% | 2% | 2% | 3% | 3% | 1% |
| 1 | 17%(2) | 18% | 20% | 22% | 20% | 13% |
| 2A | 17% | 19% | 15% | 12% | 12% | 12% |
| B | 3% | 3% | 2% | 2% | 2% | 4% |
| C | 2% | 2% | 2% | 2% | 1% | 1% |
| D | 4% | 3% | 2% | 2% | 2% | 7% |
| 2 | 26% | 28% | 21% | 18% | 16% | 25% |
| 3A | 3% | 3% | 3% | 3% | 3% | 6% |
| B | 7% | 6% | 8% | 8% | 8% | 9% |
| 3 | 10% | 9% | 11% | 11% | 11% | 15% |
| 4A | 2% | 2% | 3% | 3% | 3% | 3% |
| B(1) | 3% | 5% | 4% | 5% | 7% | 4% |
| 4 | 5% | 7% | 7% | 8% | 9% | 6% |
| 5A | 8% | 7% | 7% | 7% | 8% | 7% |
| B | 10% | 10% | 12% | 12% | 12% | 16% |
| C | 1% | 1% | 1% | 1% | 1% | 1% |
| D | 2% | 1% | 1% | 1% | 2% | 1% |
| 5 | 20% | 19% | 21% | 21% | 22% | 25% |
| 6A | 1% | 1% | 1% | 2% | 2% | 1% |
| B | 4% | 3% | 2% | 2% | 3% | 4% |
| C | 7% | 7% | 8% | 9% | 8% | 5% |
| D | 2% | 2% | 2% | 2% | 3% | 2% |
| E | 2% | 2% | 2% | 2% | 3% | 3% |
| 6 | 17% | 15% | 15% | 17% | 18% | 14% |
| 7 (1) | 5% | 3% | 5% | 4% | 4% | 1% |
| 7 | 5% | 3% | 5% | 4% | 4% | 1% |
| TOTAL: | 100 | 100 | 100 | 100 | 100 | 100 |

NOTE: (1) Installation costs only (No GFE)
(2) Subtotals rounded off

TABLE 3.3
MATERIAL FACTOR
$/ton (Actual Year)

| Cost Group | DD-931 | DDG-2 | CG-16 | CG-26 | FFG-4 | FFG-7 |
|---|---|---|---|---|---|---|
| 1A | 348.0 | 485.0 | 396.4 | 359.2 | 236.0 | 621.0 |
| B | 1,404.0 | 1,695.0 | 1,367.0 | 1,274.7 | 1,328.0 | 2,880.0 |
| C | 309.0 | 467.0 | 436.7 | 339.1 | 379.0 | 1,308.0 |
| D | 2,931.0 | 3,571.0 | 691.3 | 726.9 | 3,441.0 | 7,721.0 |
| Average | 576.0 | 763.7 | 476.6 | 434.0 | 518.0 | 1,255.0 |
| 2A | 5,572.5 | 7,160.5 | 7,258.3 | 5,258.9 | 8,179.5 | 44,407.0 |
| B | 2,941.0 | 2,593.5 | 2,369.6 | 2,164.0 | 2,641.0 | 21,408.0 |
| C | 7,603.5 | 7,965.5 | 6,365.3 | 4,927.3 | 1,172.0 | 15,597.5 |
| D | 2,978.0 | 3,508.0 | 4,206.4 | 4,708.2 | 3,228.5 | 80,386.0 |
| Average | 5,014.0 | 6,081.0 | 6,016.2 | 4,600.3 | 5,917.0 | 39,819.0 |
| 3A | 12,765.0 | 14,220.0 | 8,581.0 | 8,580.7 | 8,415.0 | 28,112.0 |
| B | 5,484.5 | 6,729.0 | 8,330.8 | 7,654.7 | 7,279.0 | 21,082.0 |
| Average | 8,740.0 | 10,078.0 | 8,442.5 | 8,099.3 | 7,864.0 | 24,615.0 |
| 4A | 4,265.0 | 6,128.0 | 3,947.0 | 4,221.4 | 8,689.0 | 26,500.0 |
| B | 535.0 | 1,076.0 | 847.2 | 838.6 | 1,886.0 | 12,376.0 |
| Average | 2,103.0 | 2,296.0 | 1,490.0 | 1,560.6 | 3,229.0 | 16,577.0 |
| 5A | 3,644.0 | 3,125.0 | 3,509.6 | 3,117.1 | 3,466.0 | 15,401.0 |
| B | 3,688.0 | 3,311.0 | 3,452.0 | 3,116.6 | 4,382.0 | 21,314.0 |
| C | 2,597.0 | 2,420.0 | 2,469.9 | 2,076.8 | 1,870.5 | 11,924.0 |
| D | 3,637.0 | 1,469.0 | 1,833.9 | 1,127.3 | 3,558.0 | 8,550.0 |
| Average | 3,518.0 | 2,950.0 | 3,192.7 | 2,796.5 | 3,662.0 | 17,450.0 |
| 6A | 2,945.0 | 2,585.5 | 2,279.1 | 1,863.6 | 1,958.0 | 12,136.0 |
| B | 2,020.0 | 1,521.0 | 1,427.2 | 1,362.0 | 2,038.0 | 6,721.0 |
| C | 2,135.0 | 1,789.5 | 2,169.9 | 1,669.2 | 1,304.0 | 4,688.0 |
| D | 1,525.0 | 2,197.5 | 1,632.3 | 1,488.8 | 2,000.5 | 4,310.0 |
| E | 3,641.0 | 3,930.0 | 3,952.3 | 3,565.6 | 4,915.0 | 15,443.0 |
| Average | 2,409.0 | 2,305.0 | 2,295.1 | 1,939.4 | 2,235.0 | 7,466.0 |
| 7 | 258.0 | 283.0 | 386.0 | 388.2 | 1,697.0 | 2,692.0 |
| Average | 258.0 | 283.0 | 386.0 | 388.2 | 1,697.0 | 2,692.0 |
| Total Ship 'eighted Average | 2,710.3 | 2,899.5 | 2,264.9 | 1,929.7 | 2,432.3 | 11,120.3 |

TABLE 3.4
LABOR FACTOR
MH/ton (Actual Year)

| Cost Group | DD-931 | DDG-2 | CG-16 | CG-26 | FFG-4 | FFG-7 |
|---|---|---|---|---|---|---|
| 1A | 262.0 | 227.0 | 165.5 | 163.9 | 201.0 | 292.0 |
| B | 625.0 | 406.0 | 369.8 | 391.9 | 385.0 | 488.0 |
| C | 301.0 | 288.0 | 532.1 | 489.1 | 295.0 | 339.0 |
| D | 269.0 | 276.5 | 516.5 | 524.9 | 262.0 | 194.0 |
| Average | 293.0 | 252.5 | 220.8 | 224.5 | 223.0 | 309.0 |
| 2A | 175.0 | 176.5 | 215.9 | 210.1 | 204.5 | 465.0 |
| B | 279.5 | 256.5 | 186.0 | 162.8 | 210.0 | 283.5 |
| C | 519.0 | 631.0 | 611.4 | 601.9 | 403.0 | 315.5 |
| D | 456.5 | 436.0 | 394.3 | 414.3 | 371.5 | 432.0 |
| Average | 241.0 | 240.5 | 250.3 | 243.2 | 243.5 | 391.5 |
| 3A | 218.0 | 192.0 | 192.8 | 181.7 | 207.5 | 217.0 |
| B | 1,563.5 | 1,396.0 | 1,596.0 | 1,475.5 | 1,732.0 | 1,677.5 |
| Average | 962.0 | 857.5 | 939.5 | 854.4 | 947.5 | 943.5 |
| 4A | 766.0 | 662.0 | 815.9 | 695.2 | 642.0 | 820.0 |
| B | 974.0 | 654.0 | 420.8 | 461.0 | 709.0 | 725.0 |
| Average | 886.0 | 656.0 | 502.8 | 511.0 | 696.0 | 753.0 |
| 5A | 1,986.0 | 1,625.0 | 1,448.6 | 1,314.6 | 1,242.0 | 1,190.0 |
| B | 967.0 | 802.0 | 933.5 | 868.8 | 805.0 | 795.0 |
| C | 306.0 | 176.0 | 195.5 | 176.2 | 134.0 | 156.0 |
| D | 520.0 | 283.0 | 370.3 | 229.6 | 202.0 | 280.0 |
| Average | 1,068.0 | 856.0 | 923.7 | 838.3 | 702.0 | 767.0 |
| 6A | 677.0 | 527.5 | 626.7 | 573.4 | 527.5 | 833.0 |
| B | 1,937.0 | 1,160.5 | 987.2 | 864.9 | 1,033.0 | 1,454.5 |
| C | 1,988.0 | 1,299.5 | 1,709.2 | 1,503.8 | 1,191.0 | 1,526.0 |
| D | 1,096.0 | 1,046.0 | 894.6 | 859.6 | 901.0 | 694.0 |
| E | 787.0 | 656.0 | 548.0 | 495.7 | 592.0 | 800.0 |
| Average | 1,408.0 | 1,009.0 | 1,092.6 | 1,000.1 | 922.0 | 1,135.0 |
| 7 | 383.0 | 252.0 | 414.1 | 321.0 | 345.0 | 275.0 |
| Average | 383.0 | 252.0 | 414.1 | 321.0 | 345.0 | 275.0 |
| Total Ship eighted Average | 496.5 | 426.6 | 427.0 | 411.5 | 424.7 | 555.0 |

TABLE 3.5
WEIGHT COMPARISON
(in Long Tons; no margins included)

| Cost Group | DD-931 | DDG-2 | CG-16 | CG-26 | FFG-4 | FFG-7 |
|---|---|---|---|---|---|---|
| 1A | 786.0 | 917.0 | 1,903.7 | 1,947.0 | 918.0 | 928.5 |
| B | 75.0 | 114.0 | 148.5 | 136.5 | 65.0 | 105.0 |
| C | 98.0 | 121.0 | 150.0 | 175.6 | 95.0 | 138.0 |
| D | 61.0 | 66.0 | 123.0 | 162.6 | 75.0 | 63.5 |
| Subtotal | 1,020.0 | 1,218.0 | 2,325.3 | 2,421.7 | 1,153.0 | 1,235.0 |
| 2A | 583.2 | 567.5 | 581.8 | 580.0 | 213.7 | 128.5 |
| B | 112.2 | 127.6 | 165.3 | 167.5 | 69.8 | 82.0 |
| C | 43.4 | 40.8 | 54.2 | 55.0 | 24.2 | 29.0 |
| D | 101.2 | 95.1 | 76.7 | 75.5 | 53.3 | 40.0 |
| Subtotal | 840.0 | 831.0 | 878.0 | 878.0 | 361.0 | 279.5 |
| 3A | 55.0 | 55.0 | 98.8 | 108.5 | 53.0 | 98.0 |
| B | 68.0 | 68.0 | 112.4 | 117.5 | 50.0 | 97.0 |
| Subtotal | 123.0 | 123.0 | 211.2 | 226.0 | 103.0 | 195.0 |
| 4A | 37.0 | 43.0 | 70.2 | 75.0 | 29.0 | 34.5 |
| B | 51.0 | 135.0 | 268.3 | 276.4 | 119.0 | 81.5 |
| Subtotal | 88.0 | 178.0 | 338.5 | 351.4 | 148.0 | 116.0 |
| 5A | 69.0 | 83.0 | 129.0 | 133.6 | 78.5 | 109.0 |
| B | 163.0 | 206.0 | 299.9 | 320.6 | 152.0 | 241.0 |
| C | 40.0 | 38.0 | 51.5 | 50.9 | 49.0 | 46.0 |
| D | 30.0 | 47.0 | 59.9 | 65.2 | 60.5 | 51.0 |
| Subtotal | 302.0 | 374.0 | 540.3 | 570.3 | 340.0 | 447.0 |
| 6A | 28.0 | 40.0 | 49.9 | 64.9 | 35.5 | 27.0 |
| B | 35.0 | 48.0 | 64.7 | 70.4 | 34.0 | 66.0 |
| C | 66.0 | 95.0 | 123.3 | 161.1 | 92.0 | 95.0 |
| D | 37.0 | 39.0 | 53.3 | 58.1 | 39.0 | 73.5 |
| E | 40.0 | 49.0 | 65.0 | 70.9 | 41.5 | 52.5 |
| Subtotal | 206.0 | 271.0 | 356.2 | 425.4 | 242.0 | 314.0 |
| 7 | 256.0 | 258.0 | 367.0 | 315.0 | 132.0 | 93.0 |
| Subtotal | 256.0 | 258.0 | 367.0 | 315.0 | 132.0 | 93.0 |
| Total Light Ship Weight | 2,835.0 | 3,253.0 | 5,016.5 | 5,187.8 | 2,479.0 | 2,679.5 |

The two-digit level factors are the BIW weighted average of material costs or labor man-hours for the three-digit SWBS elements in that group. The one-digit level factors are weighted averages of the two-digit level data. The weights are based on final weight reports with minor modifications.

### 3.2.1 Data Adjustments

The BIW data for the six ships noted provides the as-built costs, representative of the subsystems installed on these ships. Observed differences in ship costs, if explainable, can reflect differences in the subsystems of the ships as a function of technology changes, inflation, or productivity differences. If inflation and productivity are backed out of the data, the remaining differences should reflect the technology level and major characteristics of the ship subsystems, providing a series of trend lines for probable new ship configurations.

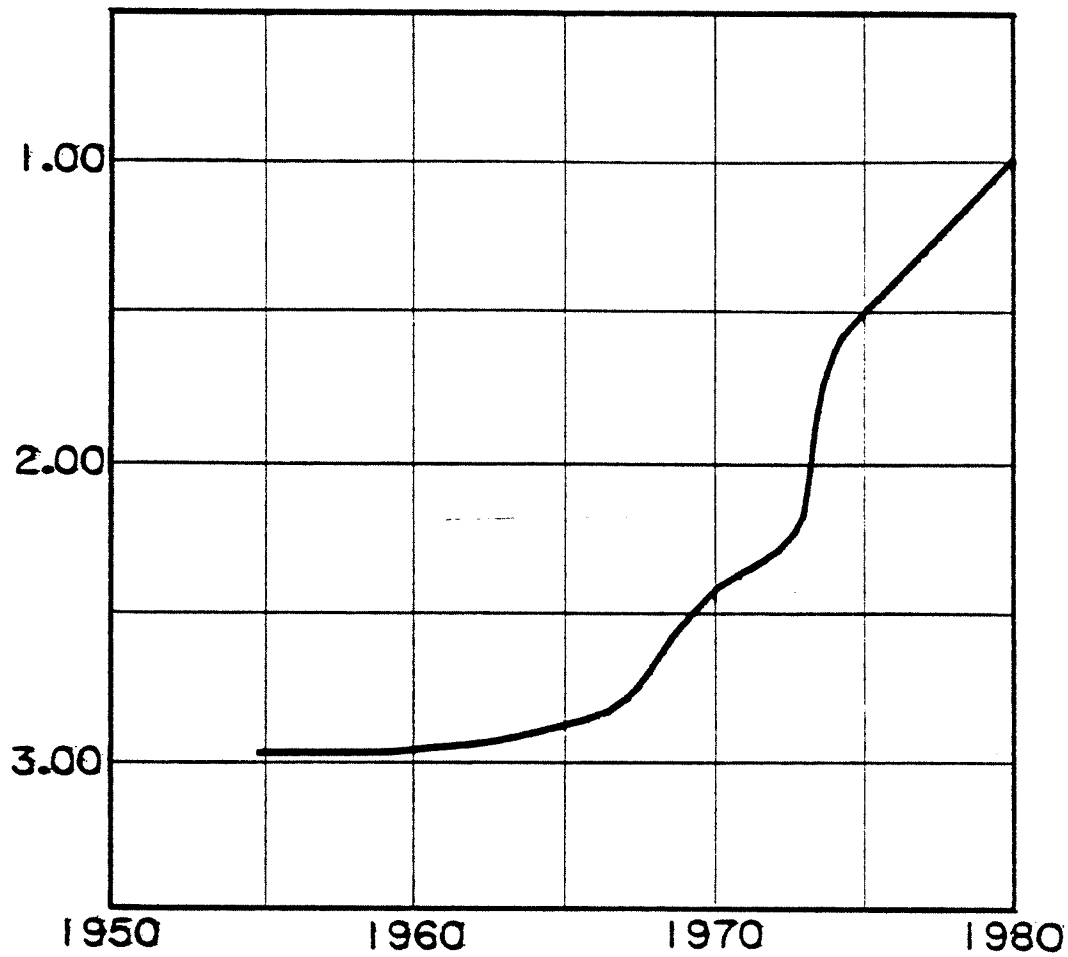
Use of raw data in this study was preceded by adjustments for differences in the age of the data. As seen in Table 3.5, sample lead ships were built between 1955 and 1977. The changes over this period of time in economics, technology, and Navy requirements significantly affected the cost of ships. Technology changes and Navy requirements are of direct interest to the algorithms included as part of the model. However, the effects of economics were factored out to ensure that all the data was treated from the same point of view. One correction made was to material costs for inflation. The raw data represents BIW costs accumulated against each vessel from the contract award to the delivery date. These program dollars were inflated from the delivery date to 1980.

- 1980 Material Cost = Material Cost (Delivery Date) x Inflation Factor

Inflation data (Figure 3.2) is based upon the steel vessel index from the Statistical Quarterly for the years included in this study (Reference 15).

# SHIPBUILDING INFLATION FACTOR

SOURCE: Ref. 15




| | |
|---|---|
| FFG-7 | 1.32 |
| FFG-4 | 2.75 |
| CG-26 | 2.90 |
| CG-16 | 2.92 |
| DDG-2 | 2.95 |
| DD931 | 2.97 |

FIGURE 3.2

Labor factors were adjusted for shipyard productivity based upon the BIW total ship labor factor curve (Figure 3.3).

- 1980 Labor Man-hours = Man-hours (Delivery Date) x Productivity Factor

Figure 3.3 diagrams BIW total ship man-hours as a productivity curve, with variations due to: (a) ten continuous years of DD/CG/FF building, followed by (b) ten years of the lack of such business before resumption on FFG-7, including (c) increased management requirements starting about 1970. The 1980 projected labor factor is BIW's estimate of an anticipated learning effect in the shipyard that is occurring because of a continuous workload. Stability in the shipyard's workload is a definite factor in total ship productivity and should be evaluated when costing a future ship. Another consideration is the shipyard's location (only BIW has been looked at here).

These adjustments are intended to remove from the raw data the known causes for any unique values in order to arrive at a set of data points (Tables 3.6 and 3.7) that show dependency on some relatable technical trends. The resultant cost factors from the set of sample ships can then be exhibited in the form of a base algorithm or algorithms that reflect the characteristics of the installed subsystems.

Additional algorithms can be generated from cost factors developed by BIW estimators to include subsystems that were not included in the basic six ships, e.g., electric drive, steel superstructures, etc. Even if only one data point off the base algorithm was available, a new algorithm proportional to the base was derived with satisfactory results.

This treatment of "scattered" data is different from the approach used in other models where "outliers" are abandoned on the presumption that unique points are not representative of a trend and, therefore, should not influence the selection of a

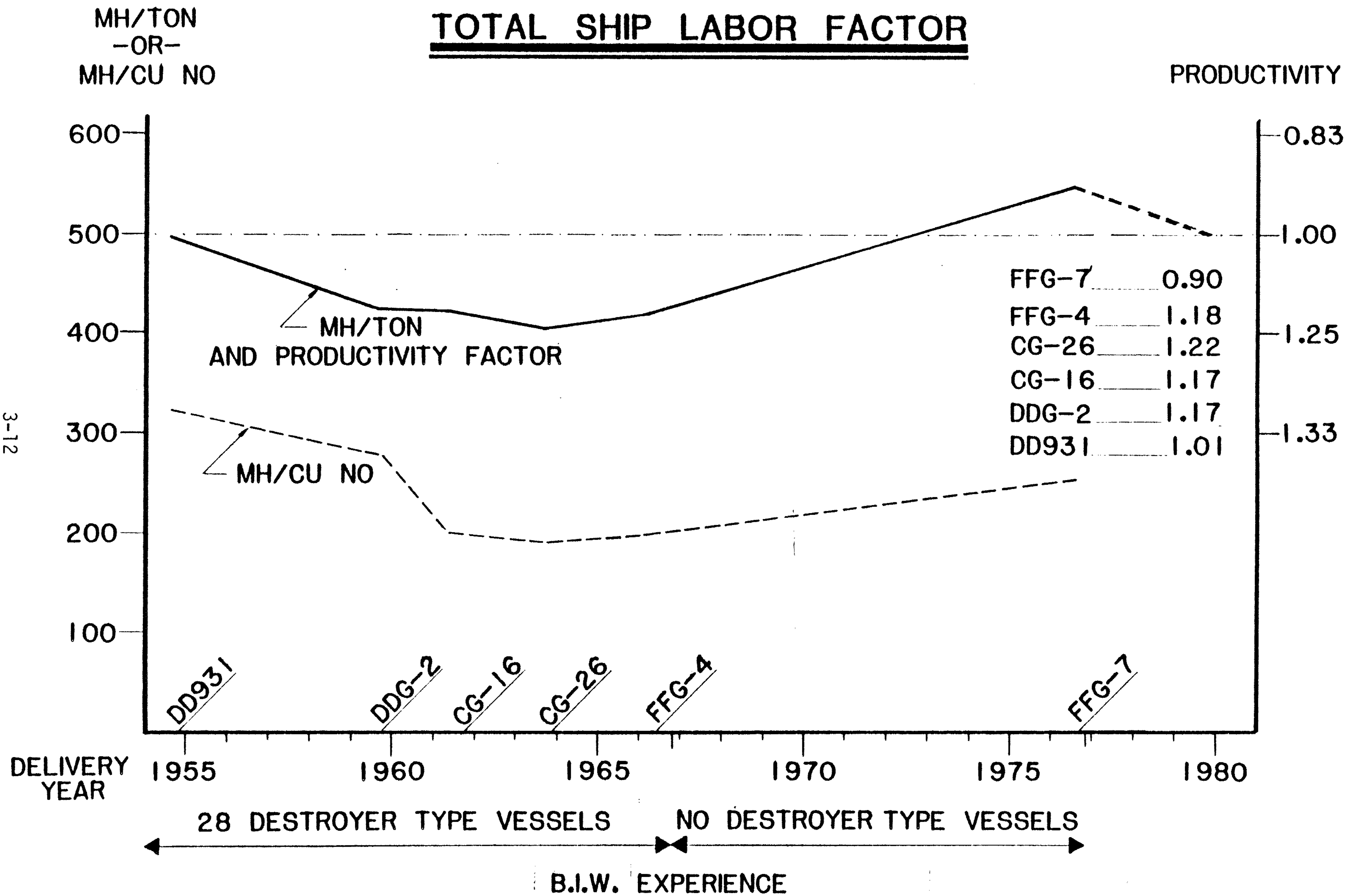

TOTAL SHIP LABOR FACTOR
MH/TON
-OR-
MH/CU NO
PRODUCTIVITY
600
500
400
300
200
100
0.83
1.00
1.25
1.33
MH/TON
AND PRODUCTIVITY FACTOR
MH/CU NO
FFG-7 0.90
FFG-4 1.18
CG-26 1.22
CG-16 1.17
DDG-2 1.17
DD931 1.01
DD931
DDG-2
CG-16
CG-26
FFG-4
FFG-7
DELIVERY
YEAR
1955
1960
1965
1970
1975
1980
28 DESTROYER TYPE VESSELS
NO DESTROYER TYPE VESSELS
B.I.W. EXPERIENCE

FIGURE 3.3

TABLE 3.6
MATERIAL COSTS - 1980 DOLLARS
(in thousands of dollars)

| Cost Group | DD-931 | DDG-2 | CG-16 | CG-26 | FFG-4 | FFG-7 |
|---|---|---|---|---|---|---|
| 1A | 812 | 1,312 | 2,204 | 2,028 | 596 | 761 |
| B | 313 | 570 | 593 | 505 | 237 | 399 |
| C | 90 | 167 | 191 | 173 | 99 | 238 |
| D | 531 | 695 | 248 | 343 | 710 | 647 |
| Subtotal | 1,745 | 2,744 | 3,236 | 3,048 | 1,642 | 2,046 |
| 2A | 9,652 | 11,988 | 12,331 | 8,846 | 4,807 | 7,532 |
| B | 980 | 976 | 1,144 | 1,051 | 507 | 2,317 |
| C | 980 | 959 | 1,007 | 786 | 64 | 597 |
| D | 895 | 984 | 942 | 1,031 | 473 | 4,244 |
| Subtotal | 12,509 | 14,907 | 15,424 | 11,713 | 5,874 | 14,691 |
| 3A | 2,085 | 2,307 | 2,476 | 2,700 | 1,226 | 3,637 |
| B | 1,108 | 1,350 | 2,734 | 2,608 | 1,001 | 2,699 |
| Subtotal | 3,193 | 3,657 | 5,207 | 5,308 | 2,227 | 6,336 |
| 4A | 469 | 777 | 809 | 918 | 693 | 1,207 |
| B | 81 | 429 | 664 | 672 | 617 | 1,331 |
| Subtotal | 550 | 1,206 | 1,473 | 1,590 | 1,314 | 2,538 |
| 5A | 747 | 765 | 1,322 | 1,208 | 748 | 2,216 |
| B | 1,785 | 2,012 | 3,023 | 2,898 | 1,832 | 6,780 |
| C | 309 | 271 | 371 | 307 | 252 | 724 |
| D | 324 | 204 | 321 | 213 | 592 | 576 |
| Subtotal | 3,155 | 3,255 | 5,037 | 4,625 | 3,424 | 10,296 |
| 6A | 245 | 305 | 332 | 351 | 191 | 433 |
| B | 210 | 215 | 270 | 278 | 191 | 586 |
| C | 419 | 502 | 781 | 780 | 330 | 588 |
| D | 168 | 253 | 254 | 251 | 215 | 418 |
| E | 433 | 568 | 750 | 733 | 561 | 1,070 |
| Subtotal | 1,474 | 1,843 | 2,387 | 2,393 | 1,487 | 3,095 |
| 7 | 196 | 215 | 414 | 355 | 616 | 330 |

TABLE 3.7

LABOR MAN-HOURS - 1980 MAN-HOURS

(In thousands of Man-hours)

| Cost Group | DD-931 | DDG-2 | CG-16 | CG-26 | FFG-4 | FFG-7 |
|---|---|---|---|---|---|---|
| 1A | 208.0 | 243.5 | 368.6 | 389.3 | 217.7 | 244.0 |
| B | 47.3 | 54.2 | 64.3 | 65.3 | 29.5 | 46.1 |
| C | 29.8 | 40.8 | 93.4 | 104.8 | 33.1 | 42.1 |
| D | 16.6 | 21.4 | 74.4 | 104.1 | 23.2 | 11.1 |
| Subtotal | 301.8 | 359.8 | 600.7 | 663.3 | 303.4 | 343.5 |
| 2A | 103.1 | 117.2 | 147.2 | 148.7 | 51.6 | 53.8 |
| B | 31.7 | 38.3 | 36.0 | 33.3 | 17.3 | 20.9 |
| C | 22.8 | 30.1 | 38.8 | 40.4 | 11.5 | 8.2 |
| D | 46.7 | 48.5 | 35.4 | 38.2 | 23.4 | 15.6 |
| Subtotal | 204.5 | 233.8 | 257.1 | 260.5 | 103.7 | 98.5 |
| 3A | 12.1 | 12.4 | 22.3 | 24.1 | 13.0 | 19.1 |
| B | 107.4 | 111.1 | 209.9 | 211.5 | 102.2 | 146.4 |
| Subtotal | 119.5 | 123.4 | 232.1 | 235.6 | 115.2 | 165.6 |
| 4A | 28.6 | 33.3 | 67.0 | 63.6 | 22.0 | 25.5 |
| B | 50.2 | 103.3 | 132.1 | 155.5 | 99.6 | 53.2 |
| Subtotal | 78.7 | 136.6 | 199.1 | 219.1 | 121.5 | 78.6 |
| 5A | 138.4 | 157.8 | 218.6 | 214.3 | 115.0 | 116.7 |
| B | 159.2 | 193.3 | 327.5 | 325.9 | 144.4 | 172.4 |
| C | 12.4 | 7.8 | 11.8 | 10.9 | 7.7 | 6.5 |
| D | 15.8 | 15.6 | 26.0 | 18.3 | 14.4 | 12.9 |
| Subtotal | 325.8 | 374.6 | 583.9 | 583.3 | 281.6 | 308.6 |
| 6A | 19.1 | 24.7 | 36.6 | 45.4 | 22.1 | 20.2 |
| B | 68.5 | 65.2 | 74.7 | 74.3 | 41.4 | 86.4 |
| C | 132.5 | 144.4 | 246.6 | 295.6 | 129.3 | 130.5 |
| D | 41.0 | 47.7 | 55.8 | 60.9 | 41.5 | 45.9 |
| E | 31.8 | 37.6 | 41.7 | 42.9 | 29.0 | 37.8 |
| Subtotal | 292.9 | 319.9 | 455.3 | 519.0 | 263.3 | 320.8 |
| 7 | 99.0 | 76.1 | 177.8 | 123.4 | 53.7 | 23.0 |

normal algorithm. The limited number of candidate ships with the subsystems of interest for this model precluded obtaining a large number of data points for each cost group, and, more specifically, for each subsystem variation within each cost group. However, based on an analysis of cost data by the BIW estimators and of ship subsystem characteristics by Gibbs & Cox, Inc., the approach taken is considered sufficiently accurate for this model, and it provides added versatility and depth as well.

Analyses of the data points included plotting the costs against various parameters, such as the cost group weight, ship's cubic number (length x beam x depth/100), complement, SHP, installed electrical generation capacity in KW, etc., to determine the data fit, establish trends, and define differences between ships along with the attendant causes.

This analysis helped define cost changes resulting from the characteristics of the different subsystems installed on the ships in the BIW cost files, thus providing the foundation for development of algorithms applicable to present day and future combatants.

### 3.2.2 Algorithms

Cost algorithms were derived by examining several past ships and plotting their data points against meaningful parameters. If enough samples were available, and if their plots provided a trend, a conclusion (algorithm) was developed to define that cost estimating relationship (CER).

The independent variables against which cost or man-hours were plotted in each group were arrived at through experimentation and with due regard for the availability of pertinent input parameters in the cost estimating stage. The selection was based upon the assumption that cost group weight would be the desired parameter unless weight provided poor data correlation or other data, e.g., SHP provided a better fit. Because of the small number of sample points and the uncertainty of future technological direction, it was decided to restrict the developed algorithms to straight line representation. The basic algorithms provide an estimate of material and labor costs in 1980 dollars and man-hours if the technical features of the ship to be costed are similar to those of the sample ships.

These algorithms were developed using the linear least squares regression technique. The primary criteria for the predictive value of each algorithm were the coefficient of the determination, $R^2$ and the number of data points included in that equation, as an indicator of the significance of the $R^2$ value. The coefficient of determination is a measure of the fit of the regression equation to the data points. An $R^2$ of 1.0 would indicate a perfect fit.

Known differences between ship examples account for many of the variations in weight/cost. The remainder of the differences were assumed to result from unknown variations, the natural dispersion of the data, and minor undefined differences in such areas as shipyard productivity and the amount of procured versus fabricated items, accommodated by the general relationship established in the algorithm. Therefore, the more knowledge of differences, the better the algorithm; however, for the objective of costing future ships, there is a practical limit to the resources available for such an endeavor. Uncertainty as to trends for future ships required that the cost equations be best estimates based on judgment and experience.

Based on the foregoing, the descriptions of the cost estimating relationships in Section 3.4 include the conditions, exceptions, and variations that qualify the conclusions. These qualifications or limitations are just as important as the CER for predicting the costs of future ships, since the user of the model should understand the basis for the algorithms and supporting data points, especially if the model is to be used to cost a subsystem not specifically covered by one of the trend lines.

Excursions from the baseline features, which are summarized in Appendix D, in some cases are taken care of through the use of supplementary trend lines or algorithms. Costs desired for subsystems that are not addressed by supplementary trend lines or algorithms may be estimated by the user of the model through comparisons of the "new" subsystem with those for which trend lines are available.

### 3.2.3 Combat Systems

In accordance with the constraints put on this model, the Basic Construction costs do not include the government furnished equipment (GFE) associated with the combat system of the ship. Other hull, mechanical and electrical (HM&E) subsystems may be considered GFE on a particular ship (propulsion gas turbines on FFG-7), but that is not usually the case, so all non-combat system HM&E costs are included in this model.

Combat systems GFE is excluded for several reasons. Equipment in the combat system is extremely costly, compared to that in other subsystems and, therefore, is usually acquired by the Navy in multi-ship lots. It is unusually high in cost per weight and volume, which distinguishes it from other equipment. Costs are unique to the various combat system equipment and are driven by the complexity of the system. Also, equipment is selected for installation on ships in a variety of combinations with regard to the ship's mission requirements and other ship characteristics. This model is restricted to the inclusion of installation costs of the combat suite that are incurred by the shipyard. Installation includes the material and labor costs for foundations, mounts, magazines and hoists, the supporting hydraulics, cables, and electrical systems and their testing.

Cost groups that are most affected by GFE considerations are Groups 4B and 7.

Group 4A contains the other non-GFE command and communication functions associated with the ship, and is treated the same as other cost groups.

### 3.3 Procedure

The foregoing discussions have provided the context for use of the algorithms in estimating the basic construction costs of FF/DD/CG types of ships.

Section 3.4 contains the descriptions and graphs for the two alternative approaches that can be taken in the use of this model; one for the one-digit level SWBS groups, and the other for the two-digit level cost groups. Each approach has an input data requirements work table, and output worksheet (Appendix E) for arriving at the cost estimate, and the requisite algorithms to perform the analysis.

If only the one-digit weight estimates, cubic number, KW, and SHP of a new ship are available, the one-digit level cost model will provide a cost estimate. One digit estimates presume a given combination of subsystems within each cost group. The disadvantage of this estimate is its inability to take into account the unusual features of a new ship, which may be different from the features included in the baseline data from which the one-digit algorithms were derived. This flexibility is built into the two-digit level cost model. Additionally, if known technical features are identified for specific cost groups, it is possible to modify the basic cost estimate through the use of supplementary trend lines. Some of these features have been examined to arrive at distinct cost differences that are identified on the appropriate algorithm plots. Other features can be taken into account if some knowledge of their differences with respect to the already identified algorithms can be determined. This would then permit interpolation between algorithms or some degree of extrapolation to determine a cost for the new features.

Much of the input for the 22 cost groups depends upon the availability of a three-digit weight estimate. When there is a lack of weight data for a particular cost group area, the alternative is to estimate the missing information. Appendices A and B may be used for this purpose by (1) comparing the known data for the new ship to the average data for the model baseline ships through percentage distributions, or (2) generating weight estimates from algorithms. In this manner, insight gained can be used to estimate the missing weights, thus permitting the user to enter the model with estimates of the required input for the 22 cost groups.

### 3.3.1 One Digit Level Cost Model

At the one-digit level, SWBS Groups 1 through 7 are each represented by a material CER and a labor CER. Where more than one independent variable (input parameter) is suggested as satisfactory for a group, cost values generated may be compared in support of each other. Concerning the algorithm limitations, where none are specified (only one trend line is shown), the equation may be used for all destroyer type vessels. If supplementary trend lines are available, the applicable equation should be used, e.g., the steam CER versus the gas turbine CER for Group 2 material.

The procedure for estimating ship construction costs at the one-digit level is as follows:

1. Begin by determining the input parameters; estimated weights (in long tons), shaft horsepower kilowatts, etc., as appropriate for each of the cost groups (Table E-1).

2. Select the one-digit level graph for material costs in Section 3.4 for each cost group. Determine the cost using the respective input parameter for that particular group. Record the cost on the output worksheet (Table E-2). Repeat this process for each group until all material costs are obtained, then total. In some cases, several trend lines are provided, depending on cost group variables. Note which trend line is used for each cost.

3. Repeat step 2 for man-hours of labor using the one-digit level graphs in Section 3.4.

4. Using the summary worksheet (Table E-3), multiply the man-hours by a man-hour cost/hour for the year concerned. (The cost per man-hour must be supplied by the user of the model.) Also, multiply by a productivity factor, as described in Figure 3.3 of this report to obtain the man-hour costs for the building year if it is not 1980.

5. Multiply the material cost by an inflation factor as described in Figure 3.2 of the report to obtain costs for the year of delivery if it is not 1980.

6. Add the material cost to the man-hour cost to obtain total basic construction cost as defined in Section 3.1.

### 3.3.2 Two-Digit Cost Model

This cost model consists of 22 cost groups, each of which is represented by at least one materials cost CER and a labor man-hours CER. Where supplementary trend lines are specified, the relationship most applicable to the system being costed should be used.

The procedure for estimating ship construction costs at the two-digit level is as follows:

1. Begin by determining the input parameters, estimated weights (in long tons), shaft horsepower, kilowatts, etc., as appropriate for each of the 22 cost groups (Table E-4).

2. Select the two-digit level graph for material costs in Section 3.4 for each cost group. Determine the cost using the respective input parameter for that particular group. Record the cost on the output worksheet (Table E-5). Repeat this process for each group until all material costs are obtained, then total. In some cases, several trend lines are provided, depending on cost group variables. Note which trend line is used for each cost.

3. Repeat step 2 for man-hours of labor using the two-digit level graphs in Section 3.4.

4. Using the summary worksheet (Table E-6), multiply the man-hours by a man-hour cost/hour for the year concerned. (The cost per man-hour must be supplied by the user of the model.) Also, multiply by a productivity factor as described in Figure 3.3 of this report to obtain the man-hour costs for the building year if it is not 1980.

5. Multiply the material cost by an inflation factor as described in Figure 3.2 of the report to obtain costs for the year of delivery if it is not 1980.

6. Add the material cost to the man-hour cost to obtain total basic construction cost as defined in Section 3.1

## 3.4 Cost Algorithms

One objective of the data plots was a good graphical representation of data points and their trends. Weights and other parameters of size that require extension of the graph can still produce adequate cost data by using the associated algorithm for that graph, instead. This interpretation applies to U.S. frigates, destroyers and cruisers, the basic characteristics of which are similar to those included in this study.

The legend, Figure 3.4, shows the graphical notations used in this model. Extended solid lines can be used with assurance. Short lines, non-extended lines, and dashed lines should be examined carefully with regard to how closely the ship under consideration fits the applications of the algorithm.

The actual data points are those listed in Tables 3.6 and 3.7. Derived data points are estimates of system costs based on return costs of similar systems.

| | |
|---|---|
| o | - Data point, actual |
| * | - Data point, derived |
| ________ | - Calculated algorithm for actual data points |
| - - - - | - Projected algorithm for actual or derived data points |

Figure 3.4. Cost Model Legend

The following sections discuss the context of each of the cost group algorithms, providing insight into their technical features and the historical perspective for use in estimating costs of future ships.

### 3.4.1 Group 1 - Hull Structure

1A Superstructure Envelope/Subdivisions
1B Superstructure
1C Foundations
1D Structural Attachments

Material Costs - The independent variables of either the Group 1 (hull) weight or the ship's cubic number can be used to estimate the Group 1 material costs. DDG-2 was omitted from the calculation due to the high cost of using HY80 when it was built. (This increase in material costs for HY80 appears only in this vessel because it was a "new" material at the time.) The basic algorithm applies only to aluminum superstructure vessels. As a function of weight or cubic number, the effect of helicopter hangars on the cost at the one-digit level is not noticeable. Because of the cost impact of making versus buying Group 1D components (that is discussed in Group 1D), the total group 1 algorithms have been modified. The modified algorithm represents the material costs curve as it graphs when the Group 1D costs for the CG-16 and CG-26 are representative of normal shipbuilding practices (See Group 1D).

CER: $ = 1,455 WT + 164,000
Variable: Group 1 Weight
Application: Aluminum Superstructure Vessels, All Hull Steels

OR

CER: $ = 340 CN - 56,000
Variable: Cubic Number
Application: Aluminum Superstructure Vessels, All Hull Steels

Labor Factor: Either the Group 1 (hull) weight or the ship's cubic number can be used to estimate the total Group 1 man-hours. Although different ships are major outliers in the 1B, 1C and 1D labor groups, the only significant outliers at this one-digit level are the CG-16 and CG 26 as defined in the Group 1D man-hours (See Group 1D). The algorithm reflects the labor function adjusted for the effects of constructing the Group 1D structural attachments instead of buying them prefabricated. Both of these algorithms apply only to vessels with aluminum superstructures.

CER: MH = 222 WT + 70,000

Variable: Group 1 Weight

Application: Aluminum Superstructure Vessels, All Hull Steels

OR

CER: MH = 51.3 CN + 42,000

Variable: Cubic Number

Application: Aluminum Superstructure Vessels, All Hull Steels

See Figures 3-5 through 3-8 for graphs of data points.

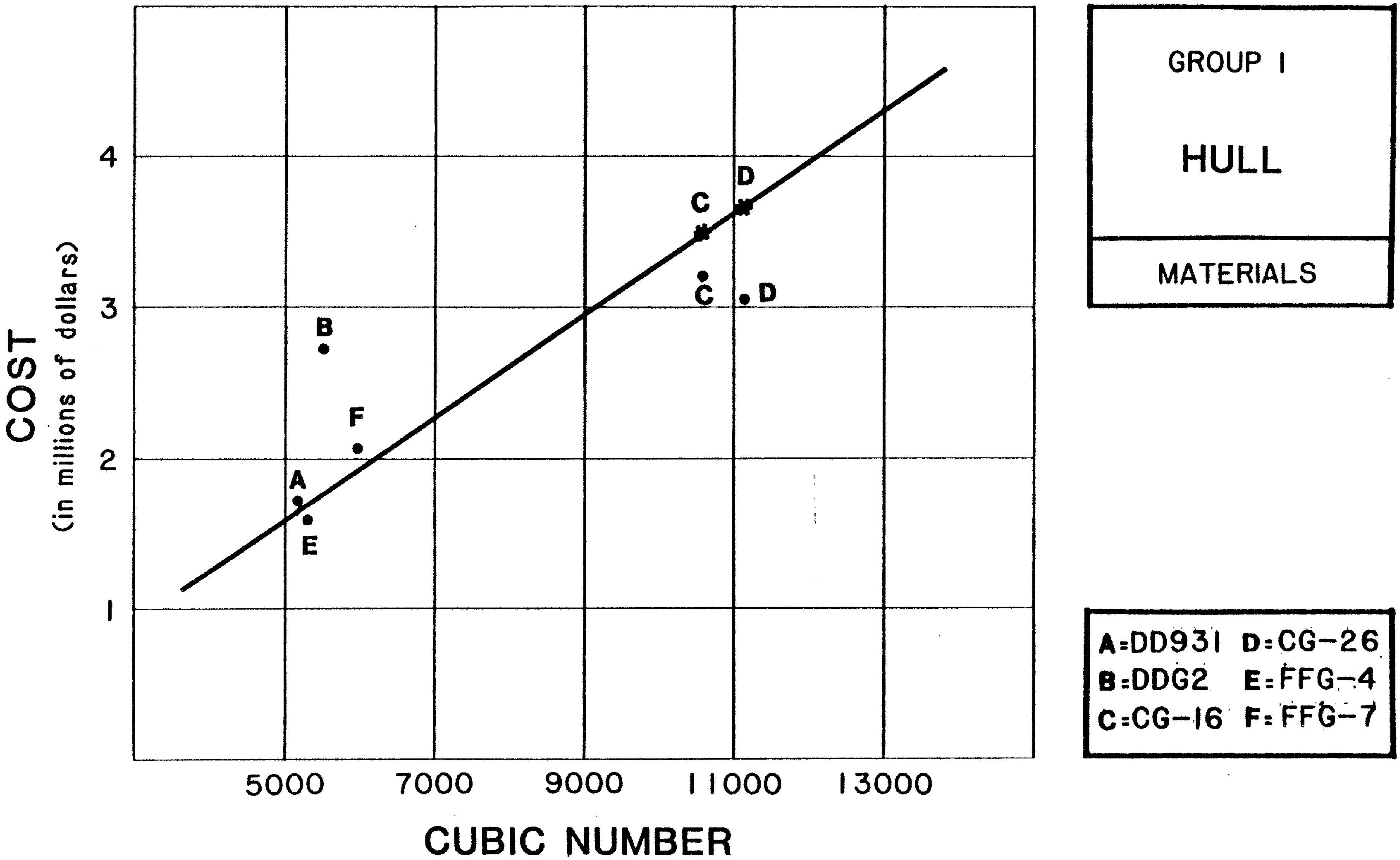

COST
(in millions of dollars)
1
2
3
4
5000
7000
9000
11000
13000
CUBIC NUMBER
A
B
C
D
E
F
GROUP I
HULL
MATERIALS
A=DD931 D=CG-26
B=DDG2 E=FFG-4
C=CG-16 F=FFG-7

Figure 3- 5

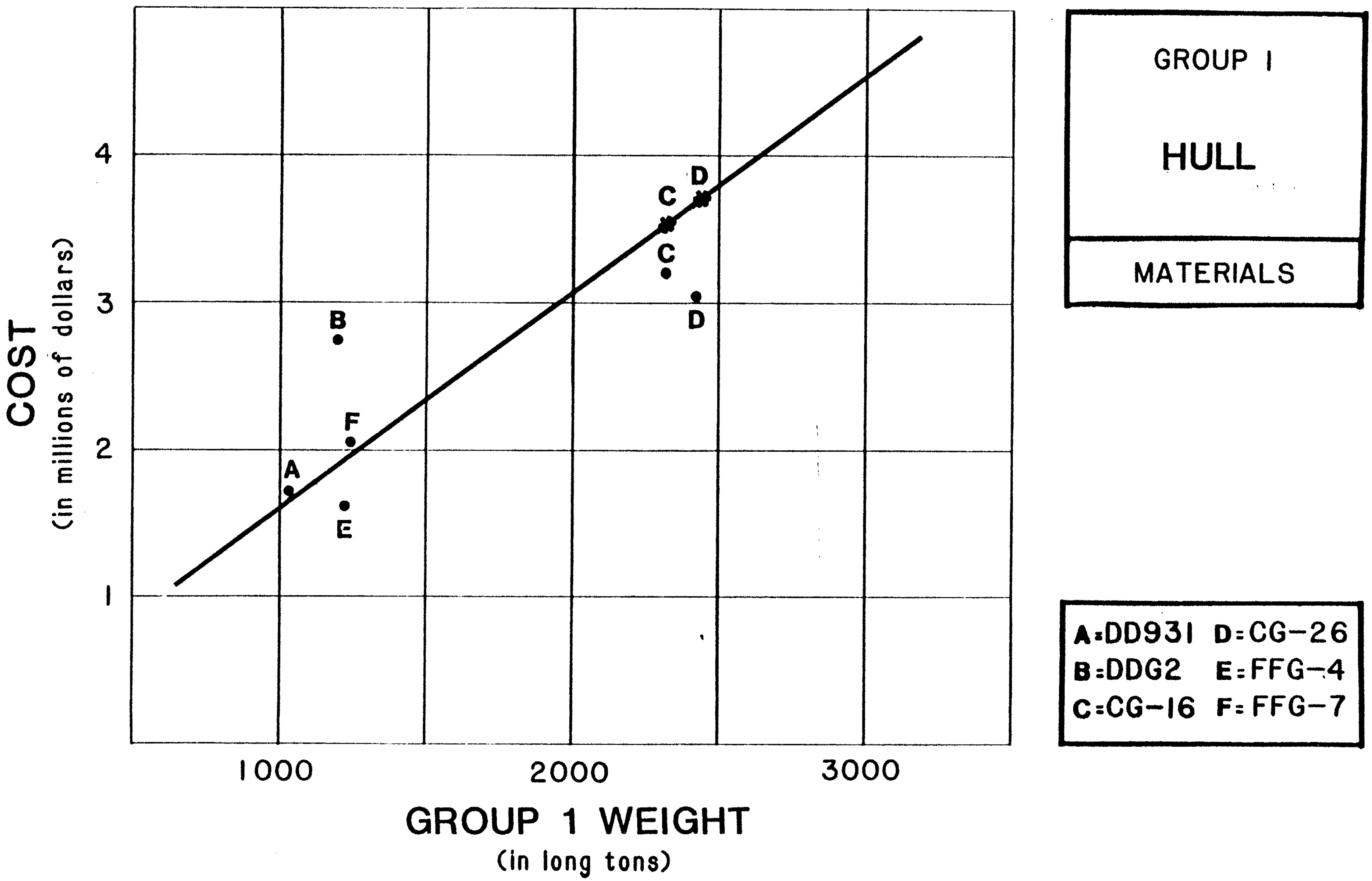
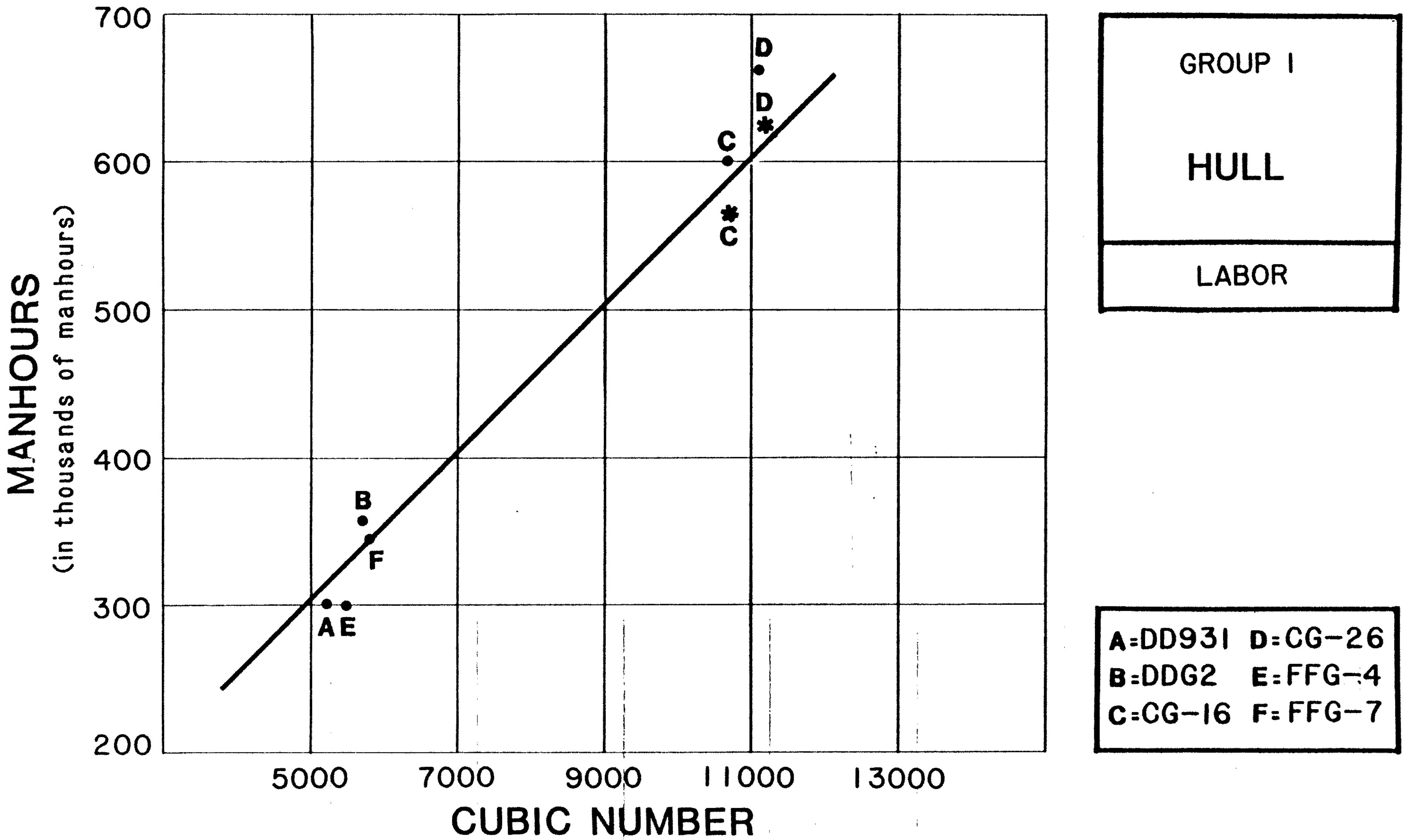

GROUP I
HULL
MATERIALS
A:DD931 D:CG-26
B:DDG2 E:FFG-4
C:CG-16 F:FFG-7
COST
(in millions of dollars)
GROUP 1 WEIGHT
(in long tons)
1000
2000
3000
1
2
3
4
A
B
C
C
D
D
E
F

Figure 3-6



700
600
500
400
300
200
5000
7000
9000
11000
13000
CUBIC NUMBER
MANHOURS
(in thousands of manhours)
A
B
C
D
E
F
GROUP I
HULL
LABOR
A=DD931 D=CG-26
B=DDG2 E=FFG-4
C=CG-16 F=FFG-7


Figure 3-7

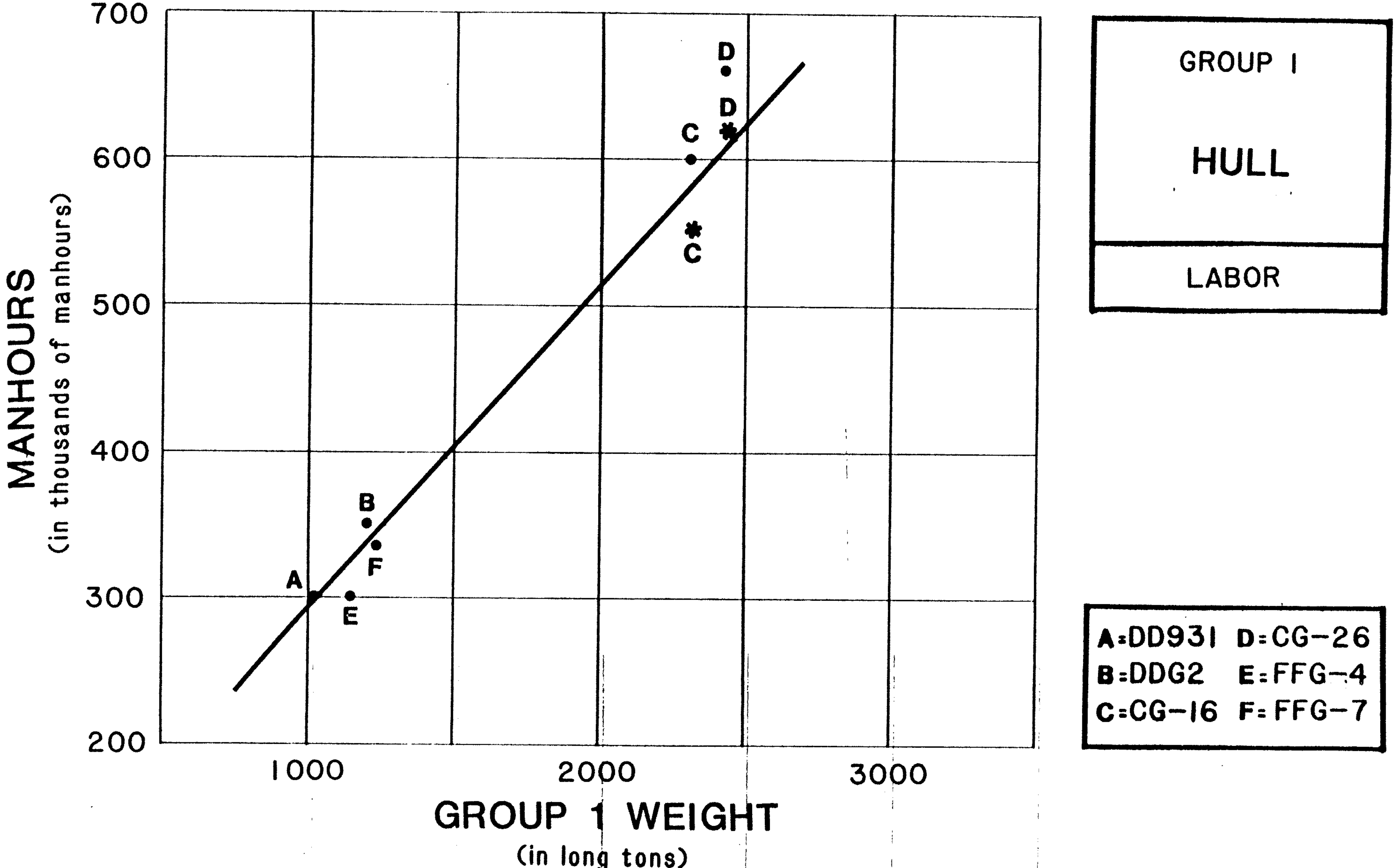

700
600
500
400
300
200
1000
2000
3000
MANHOURS
(in thousands of manhours)
GROUP 1 WEIGHT
(in long tons)
A
B
C
D
E
F
GROUP I
HULL
LABOR
A=DD931 D=CG-26
B=DDG2 E=FFG-4
C=CG-16 F=FFG-7

Figure 3-8

## Group 1A - Structural Envelope/Subdivisions

This group includes the shell plating, framing, structural bulkheads and decks.

MATERIAL FACTOR: The independent variables of either Group 1A weight or ship's cubic number can be used to estimate costs. For the ships being studied, the only major outlier is DDG-2. HY80 was used on DDG-2 for the midships three-fifths length hull steel while most vessels in this study were constructed with mild steel (MS) or high tensile steel (HTS). At the time, HY80 was just being introduced for use on naval vessels with resultant high costs associated with learning and development. CG-16 also used HY80 as shell plating (midships three-fifths length below the waterline), but the difference in hull steel does not seem to make a major difference in material costs because of the familiarity gained with HY80 by that time. Likewise, the mild steel/high tensile steel hulls do not seem to vary significantly from the aggregate algorithm. Lower costs for the CG-26 reflect the ship's position as a stretched CG-16. This resulted in factors such as the scantlings, which were the same for the major structure rather than increased to suit the increase in length.

CER: $\$ = 258\ CN - 687{,}000$
Variable: Cubic Number
Application: HTS, MS, HY80 hulls

OR

CER: $\$ = 1{,}304\ WT - 411{,}000$
Variable: Group 1A Weight
Application: HTS, MS, HY80 hulls

LABOR FACTOR: Either cubic number or the cost group weight can be used to estimate the Group 1A man-hours regardless of the type of hull steel used.

CER: MH = 28.8 CN + 68,600
Variable: Cubic Number
Application: HTS, MS, HY80 hulls

OR

CER: MH = 146 WT + 98,600
Variable: Group 1A Weight
Application: HTS, MS, HY80 hulls

See Figures 3-9 through 3-12 for graphs of data points.

Group 1B - Superstructure

This Group includes the deckhouse structure, helicopter hangars, etc., but does not include masts, stacks and macks.

MATERIAL FACTOR: Superstructure cost can be estimated as a function of the Group 1B weight with one algorithm for aluminum superstructures and another for steel. The steel costs were estimated by BIW for equivalent steel superstructures, as developed by Gibbs & Cox, for the ships in this study. The Group 1B weight for a steel superstructure can be estimated as approximately two times the weight of an equivalent volume aluminum superstructure. Although a straight weight ratio of steel to aluminum is 3 to 1, for structural systems of equivalent strength (plating and framing), the weight ratio is 2 to 1.

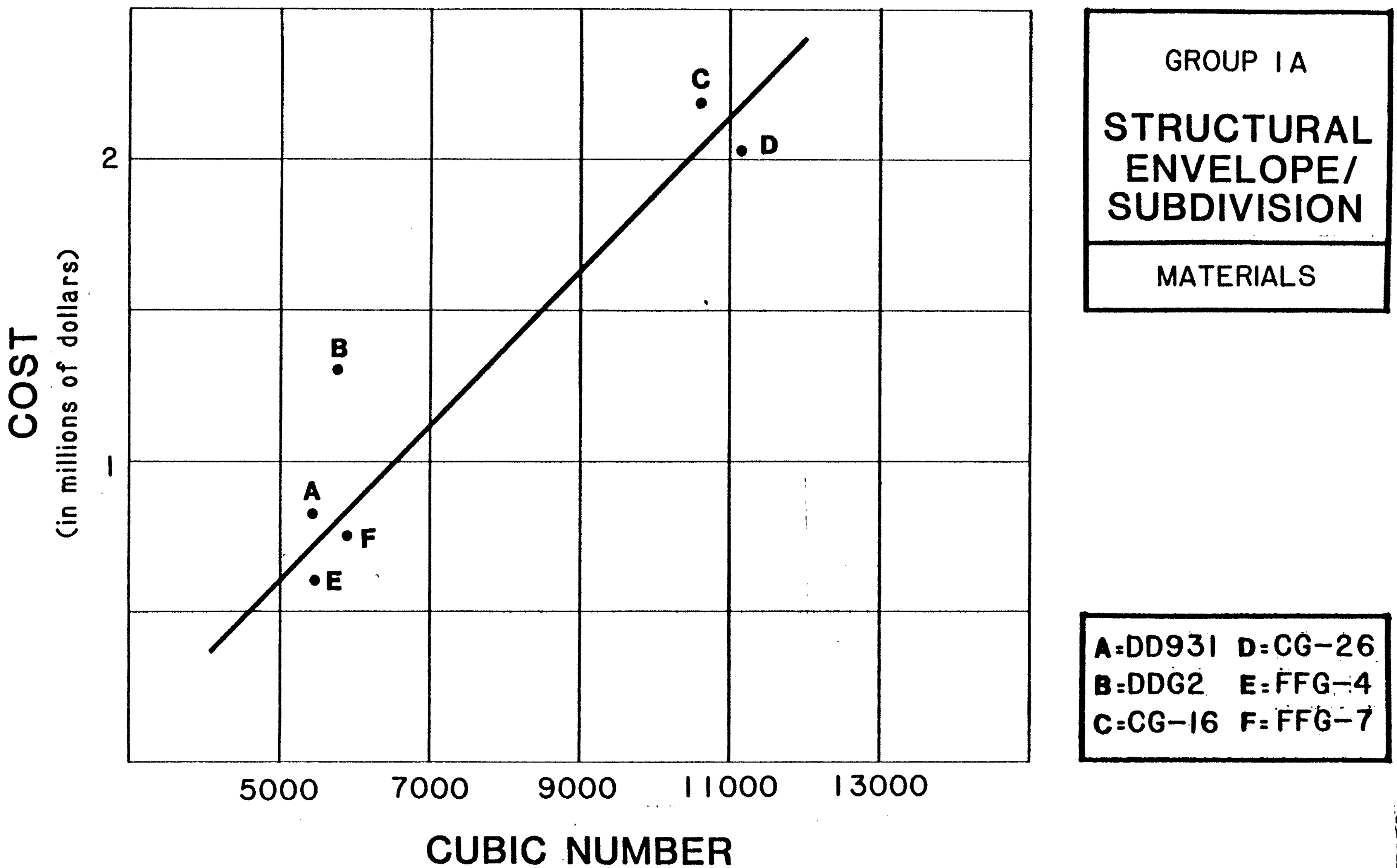

GROUP IA
STRUCTURAL ENVELOPE/ SUBDIVISION
MATERIALS
COST (in millions of dollars)
2
1
5000
7000
9000
11000
13000
CUBIC NUMBER
A
B
C
D
E
F
A=DD931 D=CG-26
B=DDG2 E=FFG-4
C=CG-16 F=FFG-7

Figure 3- 9

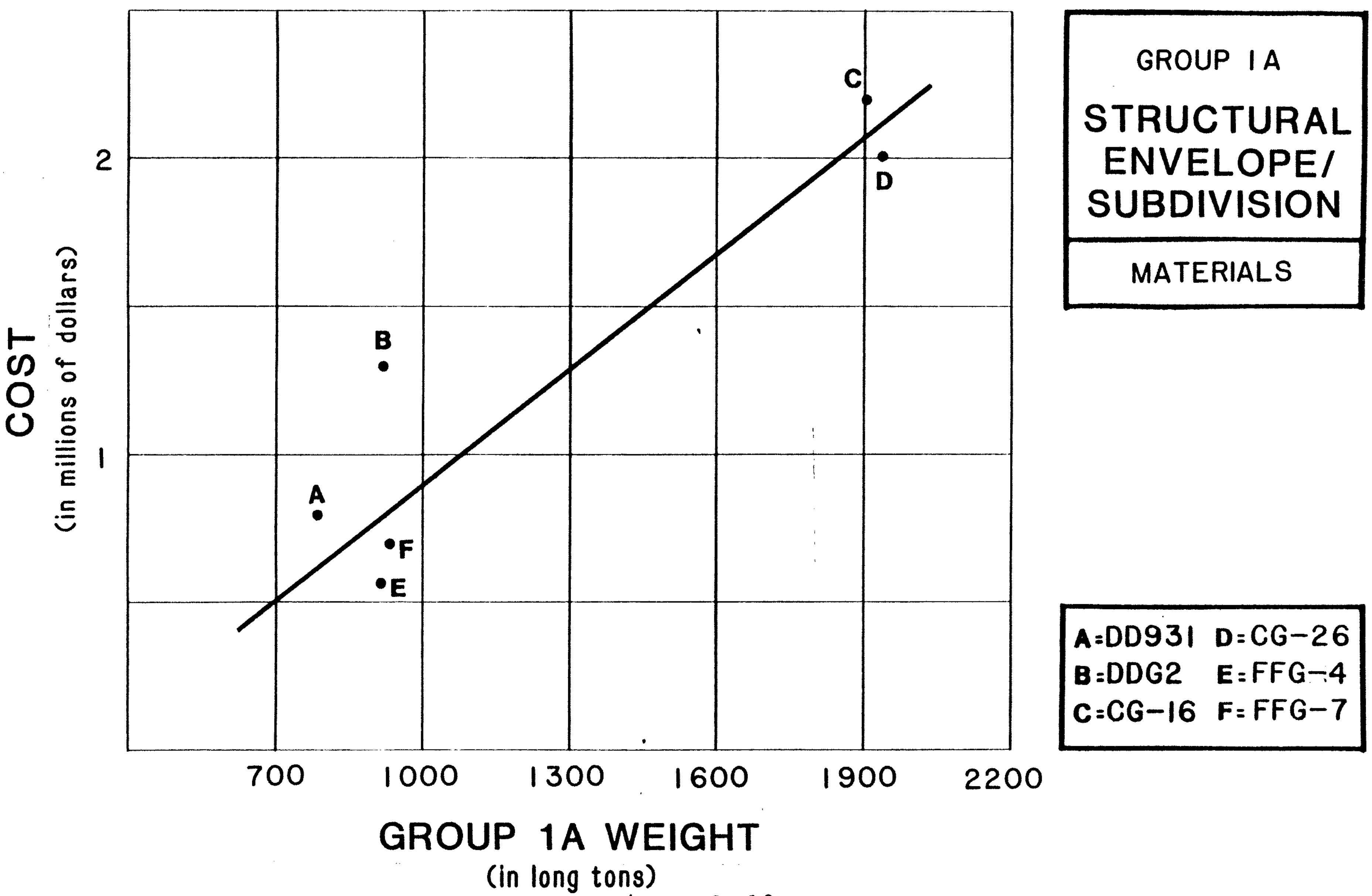

GROUP 1A
STRUCTURAL ENVELOPE/ SUBDIVISION
MATERIALS
C
D
B
A
F
E
2
1
COST
(in millions of dollars)
700
1000
1300
1600
1900
2200
GROUP 1A WEIGHT
(in long tons)
A=DD931 D=CG-26
B=DDG2 E=FFG-4
C=CG-16 F=FFG-7

Figure 3-10

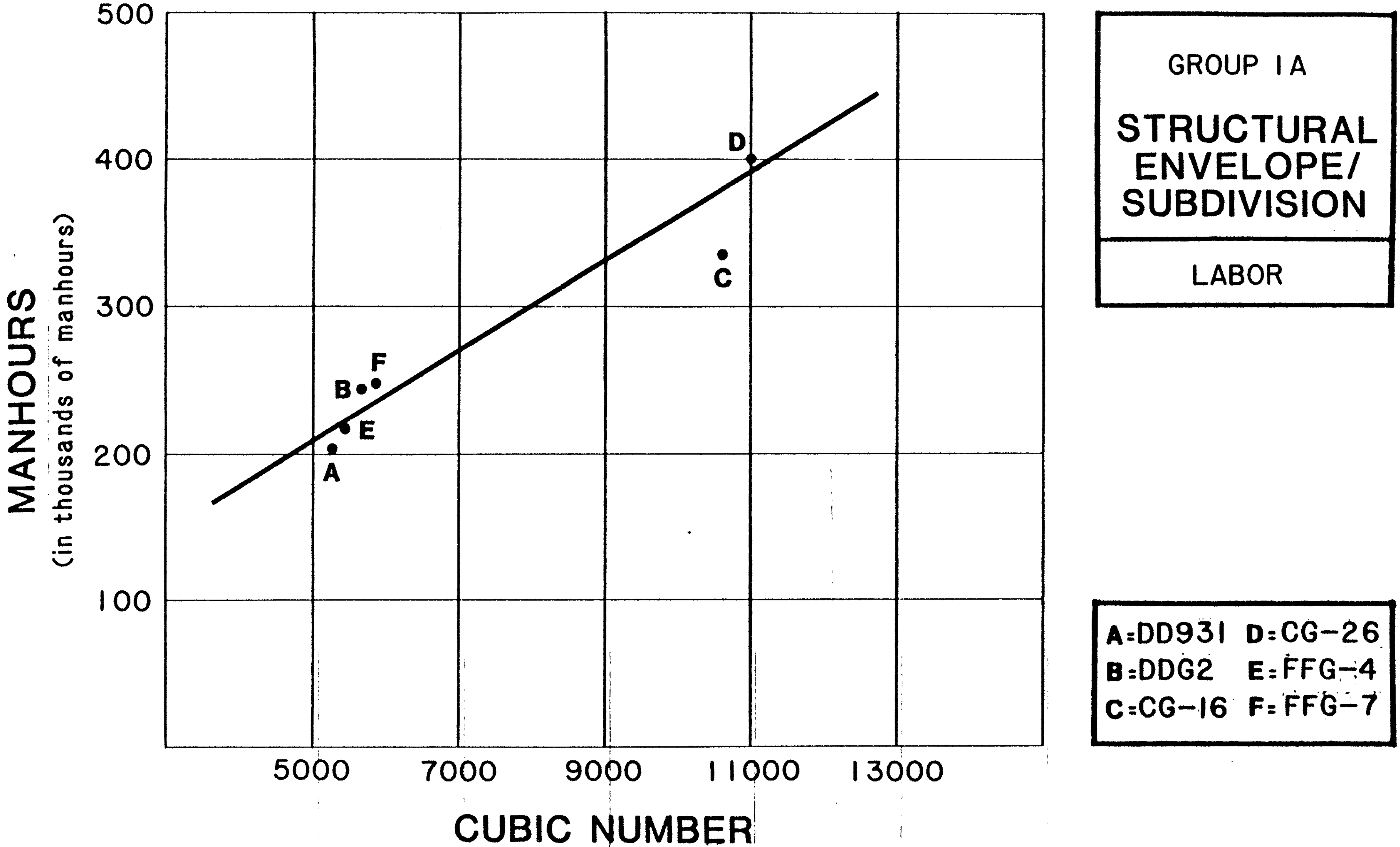

500
400
300
200
100
MANHOURS
(in thousands of manhours)
5000
7000
9000
11000
13000
CUBIC NUMBER
A
B
C
D
E
F
GROUP IA
STRUCTURAL ENVELOPE/ SUBDIVISION
LABOR
A=DD931 D=CG-26
B=DDG2 E=FFG-4
C=CG-16 F=FFG-7

Figure 3-11

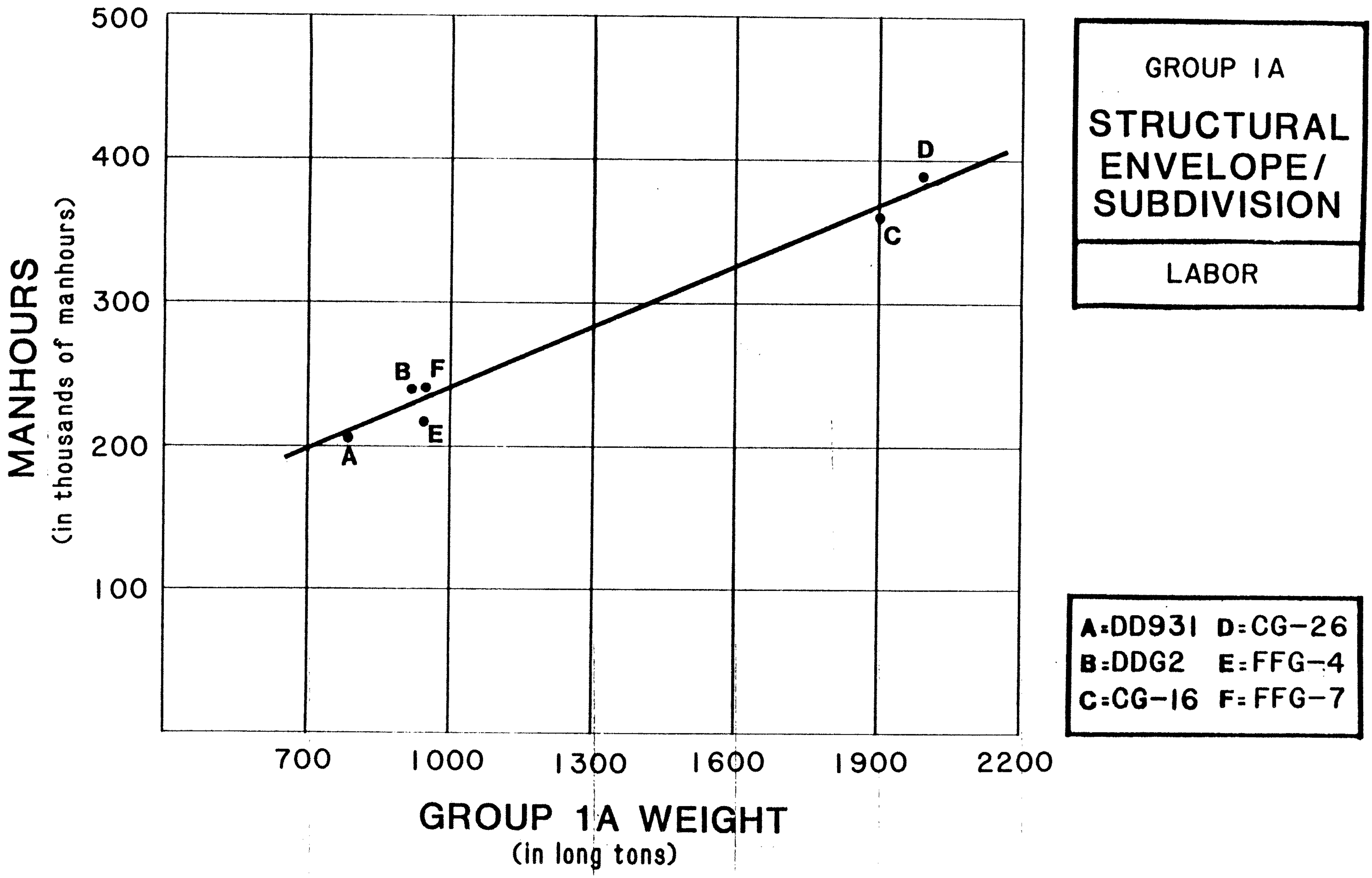

GROUP 1A
STRUCTURAL ENVELOPE/ SUBDIVISION
LABOR
MANHOURS
(in thousands of manhours)
500
400
300
200
100
700
1000
1300
1600
1900
2200
GROUP 1A WEIGHT
(in long tons)
A
B
C
D
E
F
A:DD931 D:CG-26
B:DDG2 E:FFG-4
C:CG-16 F:FFG-7

Figure 3- 12

The inclusion of helicopter hangars does not seem to be a major determinant in the cost when plotted against weight. When plotted as a function of volume, the 1B material costs for the vessels with helicopter hangars fall below the line because the hangar is primarily empty volume. There were not enough data points to predict a material cost algorithm against volume for ships with and without helicopters since this distinction was very small.

CER: $ = 4,020 WT + 5,000
Variable: Group 1B Weight
Application: Aluminum Superstructures

CER: $ = 850 WT
Variable: Group 1B Weight
Application: Steel Superstructures

LABOR FACTOR: Group 1B man-hours are also estimated as a function of the superstructure weight. The algorithm for steel superstructures was estimated for equivalent steel superstructures for the ships in this study. DD-931 is a major outlier for labor because it was the first aluminum superstructure constructed by BIW, and several problems associated with this "first" caused the labor figures to be high. One consideration in the extrapolation of labor figures with the aluminum algorithm is that all of the ships for which data is plotted were constructed before the advent of machine cutting (plasma burning) for aluminum. An estimation of the labor savings as a result of this is 2% or about 1000 man-hours for an FFG-7 superstructure.

CER: MH = 449 WT + 1,000
Variable: Group 1B Weight
Application: Aluminum Superstructures

CER: MH = 300 WT
Variable: Group 1B Weight
Application: Steel Superstructures

See Figures 3-13 and 3-14 for graphs of data points.

Group 1C - Foundations

This group includes the foundations for propulsion plant machinery, auxiliaries and other equipment.

MATERIAL FACTOR: The material costs for foundations are a function of the type of propulsion plant and whether the foundations are shock hardened or not. The data for two cases: steam plant, non-shock hardened and gas turbine plant, shock hardened, are represented here. The scatter of the steam plant foundations is due to an evolutionary change in design criteria from the 50's through the 60's with regard to underwater shock and to inconsistencies in the classification of the foundation shock levels, and in the classification of foundation weights. In most 1950 and 1960 vintage vessels, the ship's main propulsion machinery is hard mounted with only limited attention given to foundation design. Also shafting, most auxiliaries, and piping systems were designed to carry only

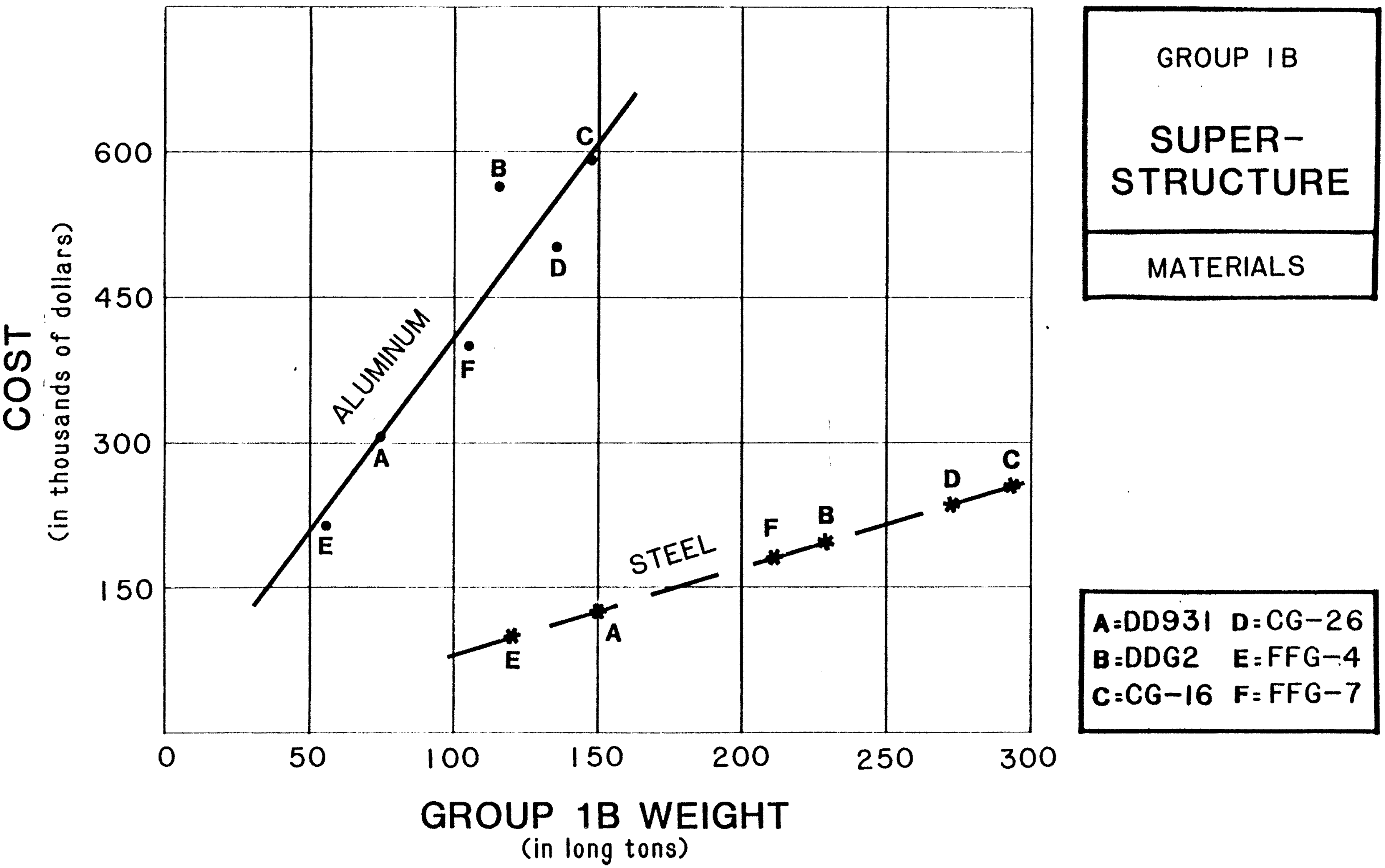

GROUP 1B
SUPER-
STRUCTURE
MATERIALS
COST
(in thousands of dollars)
600
450
300
150
0
50
100
150
200
250
300
GROUP 1B WEIGHT
(in long tons)
ALUMINUM
STEEL
A
B
C
D
E
F
A=DD931
B=DDG2
C=CG-16
D=CG-26
E=FFG-4
F=FFG-7

Figure 3-13

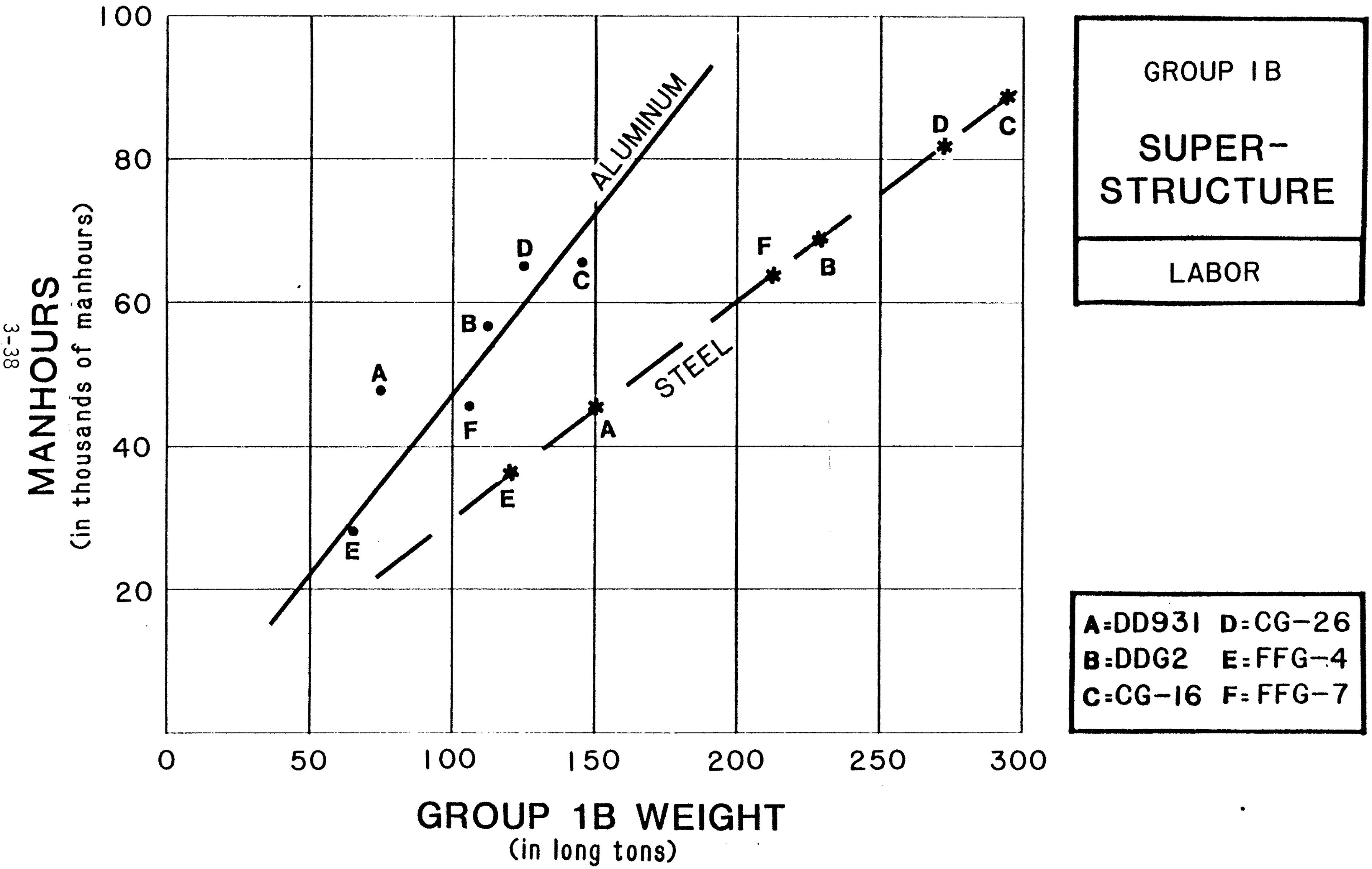

GROUP 1B
SUPER-
STRUCTURE
LABOR
A=DD931 D=CG-26
B=DDG2 E=FFG-4
C=CG-16 F=FFG-7
ALUMINUM
STEEL
MANHOURS
(in thousands of manhours)
GROUP 1B WEIGHT
(in long tons)
0
50
100
150
200
250
300
20
40
60
80
100

Figure 3-14

limited static equivalent shock loads. Later vessels were designed with more attention given to high shock and self noise limitation as seen in the FFG-7 foundations. The higher material cost is not caused by the actual material content, but is because a portion of the foundation is bought already fabricated as a unit along with the gas turbine itself. This unit or bedplate contains a shock mounting system for the prime mover, thus, some of the increased shock requirements are reflected in the materials costs. The same would be true if shock hardened foundations were acquired with steam plants in the same manner.

CER: $\$ = 1{,}760\ WT - 5{,}000$
Variable: Group 1C Weight
Application: Gas Turbine Plant

CER: $\$ = 1{,}120\ WT + 1{,}000$
Variable: Group 1C Weight
Application: Steam Plant

LABOR FACTOR: The man-hours for Group 1C are also a function of the plant and foundation type. The gas turbine foundation algorithm is lower than the steam plant algorithm because the lighter weight and simpler configuration of the gas turbine plant provides for a simpler foundation.

CER: $MH = 1{,}000\ WT - 67{,}800$
Variable: Group 1C Weight
Application: Steam Plant

CER: MH = 633 WT - 45,000

Variable: Group 1C Weight Application: Gas Turbine Plant

See Figures 3-15 and 3-16 for graphs of data points.

Group 1D - Structural Attachments

This group includes structural castings, forgings, doors, hatches, sonar dome, masts and towers.

MATERIAL FACTOR: The individual plots for these groups are misleading in that the CG-16, CG-26 have low material factors and high labor factors because many of the structural attachments were constructed by the yard instead of buying the item which is the usual practice. After modifying the data for CG 16 and CG 26 to simulate ships whose structural attachments were bought, only the DD-931 is an outlier which is understandable as it is much older than the others. The projected algorithm of cost versus weight should yield acceptable costs for the larger destroyers with 'bought' structural attachments.

CER: $ = 1,540 WT + 571,000

Variable: Group 1D Weight

Application: "Bought" Structural Attachments

LABOR FACTOR: As with the material algorithm, the labor algorithm used modified data for the larger vessels whose structural attachments were made. The FFG-7 is an outlier when man-hours are

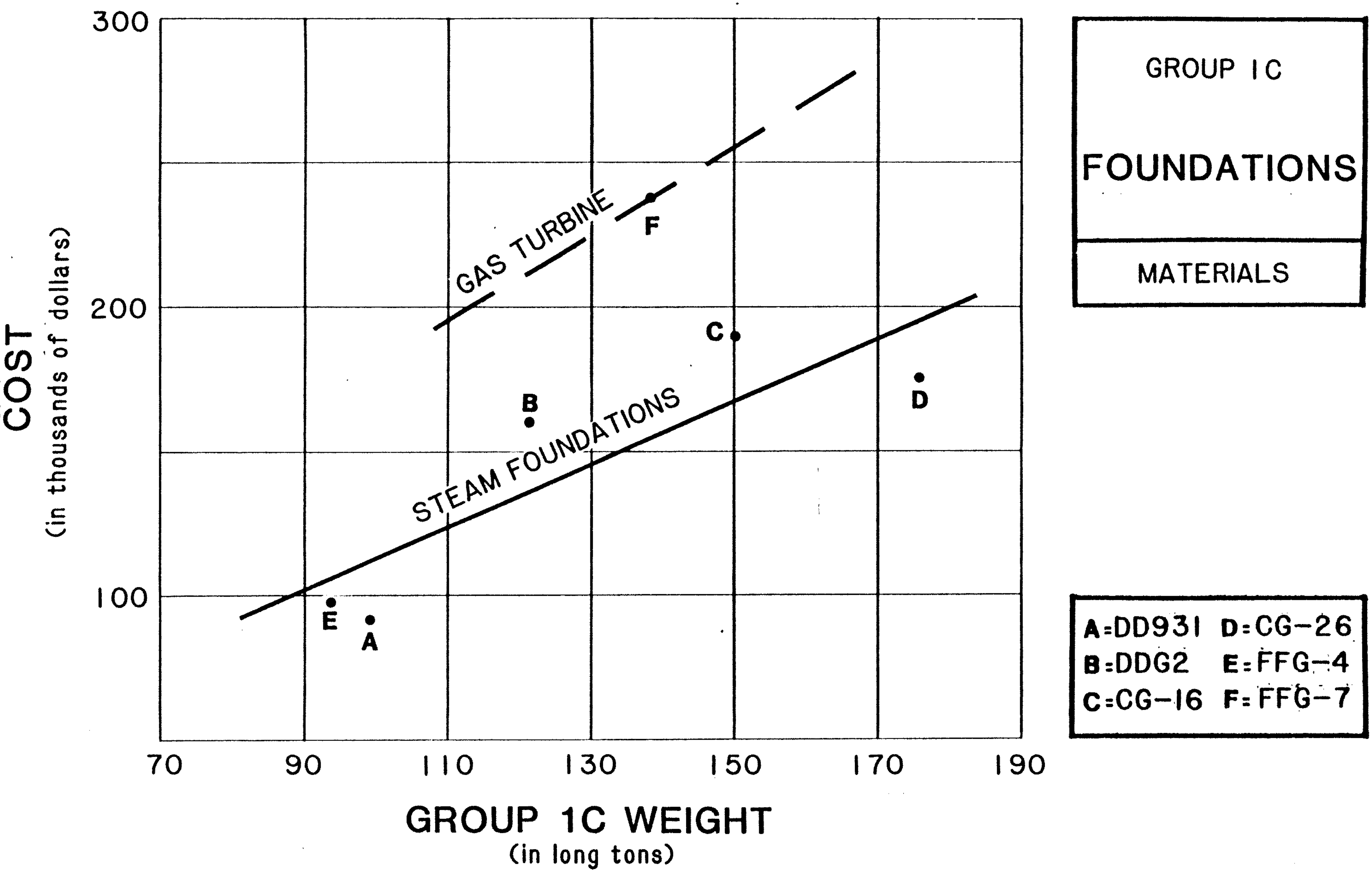

300
200
100
COST
(in thousands of dollars)
70
90
110
130
150
170
190
GROUP 1C WEIGHT
(in long tons)
GAS TURBINE
STEAM FOUNDATIONS
A
B
C
D
E
F
GROUP 1C
FOUNDATIONS
MATERIALS
A=DD931 D=CG-26
B=DDG2 E=FFG-4
C=CG-16 F=FFG-7

Figure 3-15

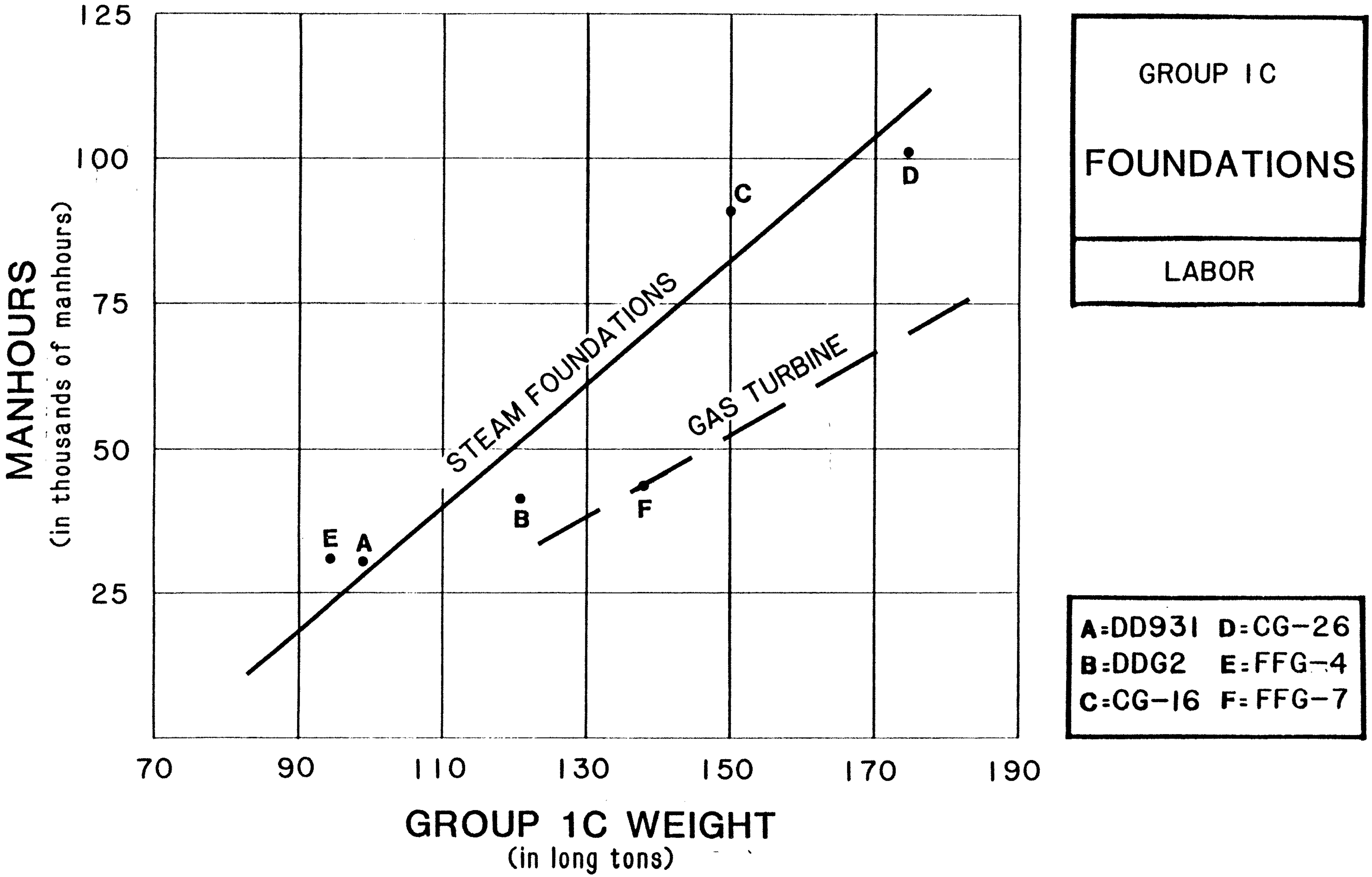

GROUP 1C
FOUNDATIONS
LABOR
MANHOURS
(in thousands of manhours)
125
100
75
50
25
70
90
110
130
150
170
190
GROUP 1C WEIGHT
(in long tons)
STEAM FOUNDATIONS
GAS TURBINE
A
B
C
D
E
F
A=DD931 D=CG-26
B=DDG2 E=FFG-4
C=CG-16 F=FFG-7

Figure 3-16

graphed versus weight, because it has a small sonar system and a single anchor.

CER: MH = 484 WT - 14,600
Variable: Group 1D Weight
Application: "Bought" Structural Attachments

See Figures 3-17 and 3-18 for graphs of data points.

3.4.2 Group 2 - Propulsion System

2A - Propulsion Energy System
2B - Propulsion Train System
2C - Propulsion Gases System
2D - Propulsion Service System

MATERIAL COSTS: The main costs of a propulsion plant are a function of the choice of propulsion plant type and the number of shafts. These costs are influenced by the endurance, cruising speed, maximum sustained speed desired, length of shafting and propulsion type (fixed pitch versus controllable pitch). The differences between propulsion plant types are shown by the graph of shaft horsepower (SHP) versus cost. The differences in plant type and number of shafts are shown.

Factors that tend to drive the cost of the gas turbines above the steam plant include auxiliary propulsion systems, controllable pitch propellers, and automated controls. The electric propulsion curve has an even higher cost associated with the motors versus a relatively low cost associated with the geared plant.

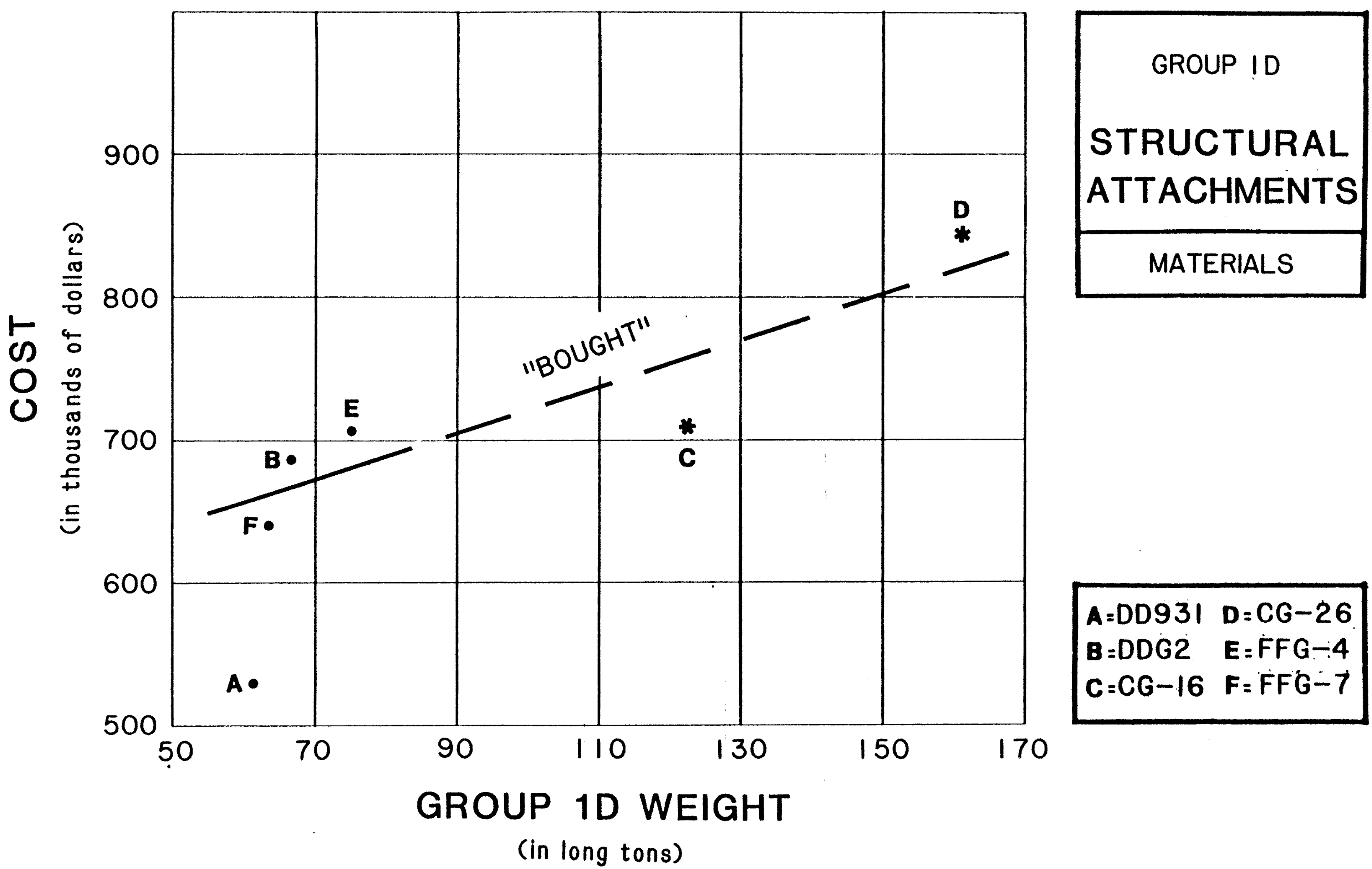

GROUP 1D
STRUCTURAL ATTACHMENTS
MATERIALS
COST
(in thousands of dollars)
900
800
700
600
500
50
70
90
110
130
150
170
GROUP 1D WEIGHT
(in long tons)
"BOUGHT"
A
B
C
D
E
F
A=DD931
B=DDG2
C=CG-16
D=CG-26
E=FFG-4
F=FFG-7

Figure 3- 17

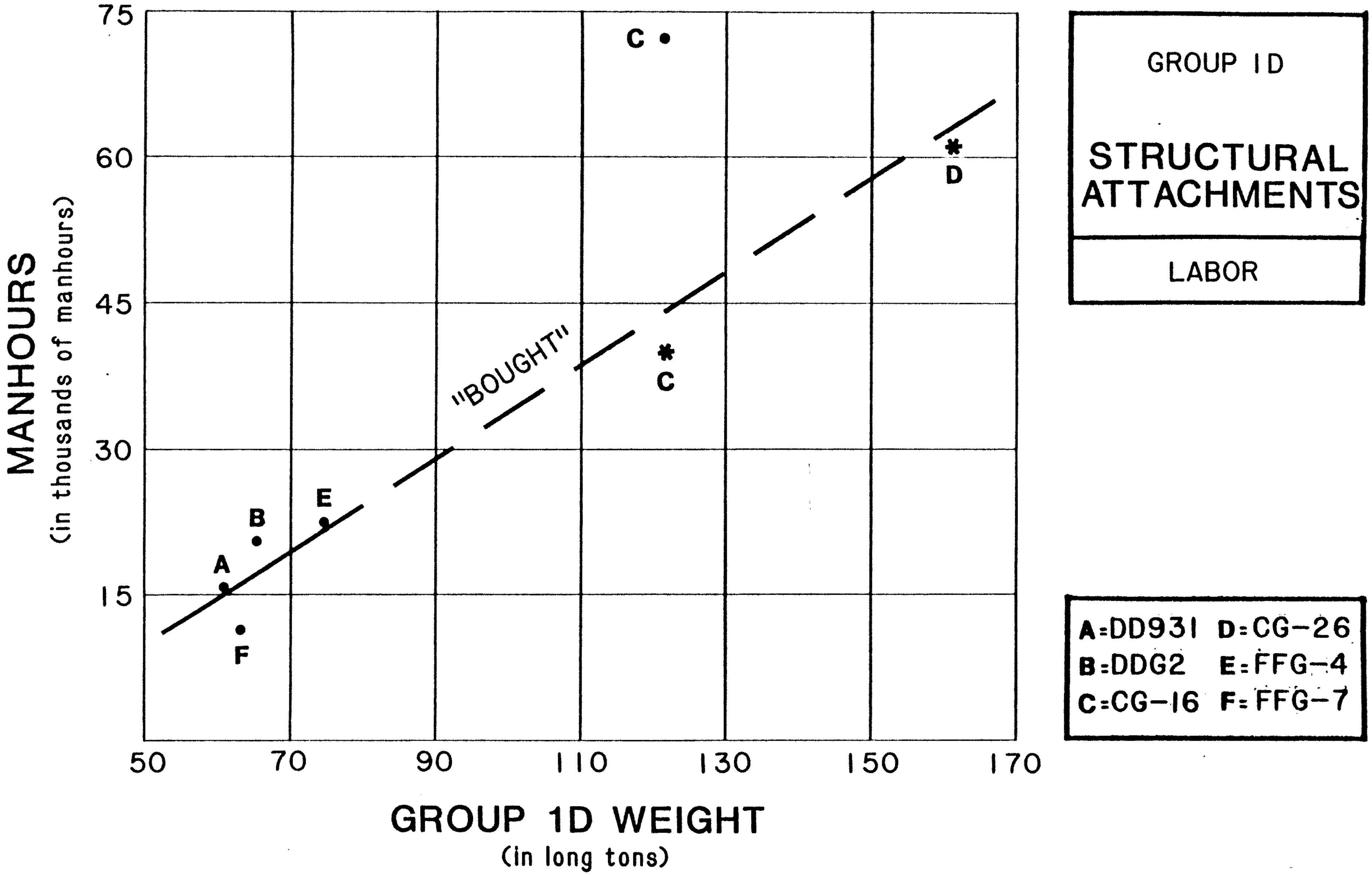

GROUP 1D
STRUCTURAL ATTACHMENTS
LABOR
MANHOURS
(in thousands of manhours)
GROUP 1D WEIGHT
(in long tons)
"BOUGHT"
75
60
45
30
15
50
70
90
110
130
150
170
A
B
C
D
E
F
A=DD931 D=CG-26
B=DDG2 E=FFG-4
C=CG-16 F=FFG-7

Figure 3- 18

The CG-26 was dropped out of the data because it was involved in a multiple buy in it's engineering costs. It is a modification of the CG-16 so it is not a "lead" ship as the rest of them are (with the exception of the DDGX which is included as a point of reference for new technologies).

The curves are undefined in the area where the selection of a single shaft or twin shaft plant would be unclear.

CER: $ = 114.4 SHP + 1,870,000
Variable: Shaft horsepower
Application: Steam, single shaft

CER: $ = 114.4 shp + 5,700,000
Variable: Shaft horsepower
Application: Steam, twin shaft

CER: $ = 358.3 SHP + 0
Variable: Shaft horsepower
Application: Geared Gas Turbine, single shaft

CER: $ = 358.3 SHP + 12,736,000
Variable: Shaft horsepower
Application: Geared Gas Turbine, twin shaft

CER: $ = 358.3 SHP + 12,338,000
Variable: Shaft horsepower
Application: Electric Gas Turbine, single shaft

CER: $ = 358.3 SHP + 19,219,000.
Variable: Shaft horsepower
Application: Electric Gas Turbine, twin shaft

LABOR COSTS: Man-hours versus shaft horsepower (SHP) correlates very well looking at the data provided for the steam propulsion ships. The other propulsion systems are plotted as individual points of reference with short, calculated curves provided.

CER: MH = 3.11 SHP - 2,700
Variable: Shaft horsepower
Application: Steam

CER: 3.11 SHP - 29,000
Variable: Shaft horsepower
Application: Geared Gas Turbine

CER: 3.14 SHP + 31,700
Variable: Shaft horsepower
Application: Electric Gas Turbine

See Figures 3-19 and 3-20 for graphs of data points.

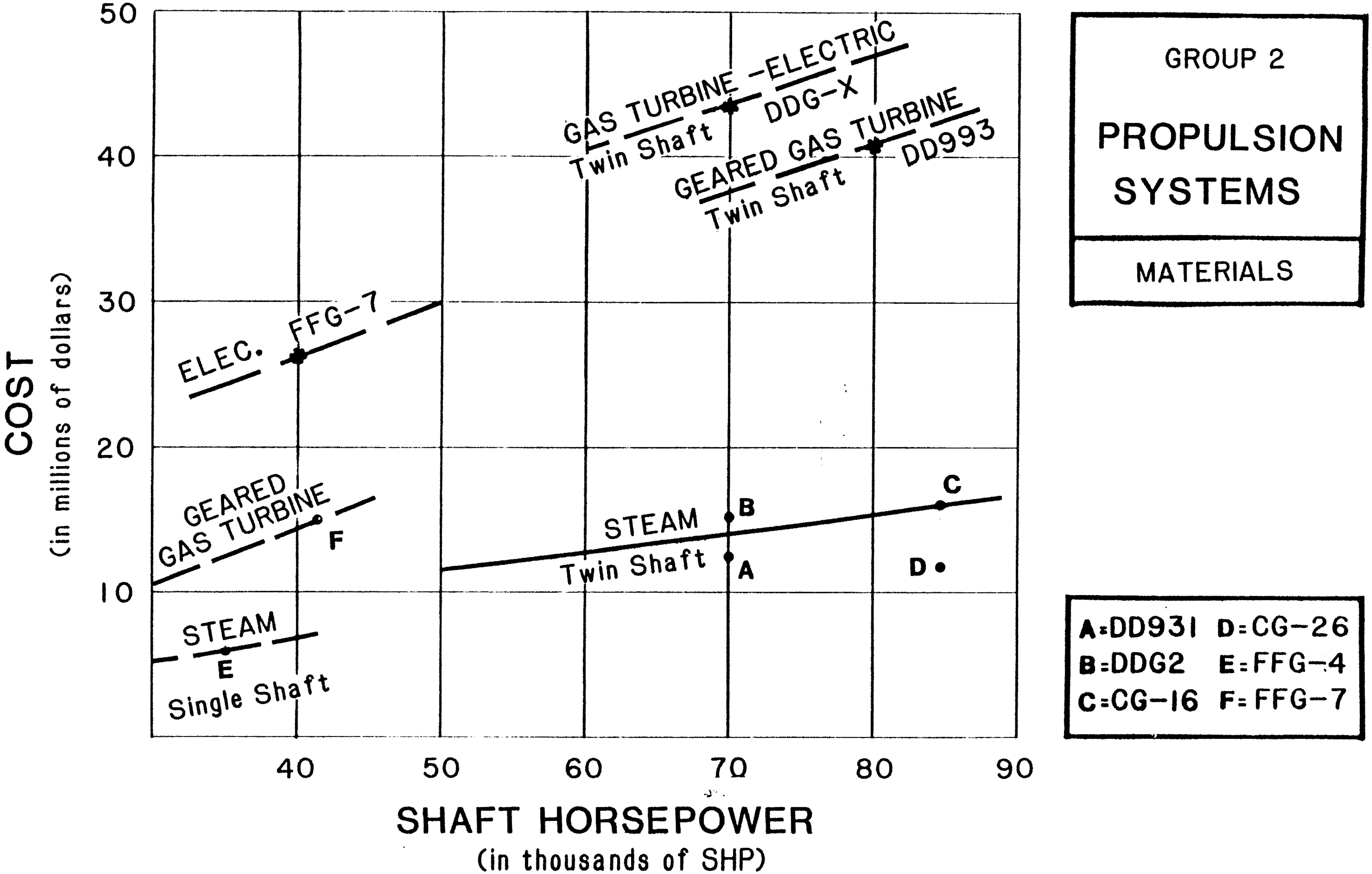

GROUP 2
PROPULSION SYSTEMS
MATERIALS
COST
(in millions of dollars)
SHAFT HORSEPOWER
(in thousands of SHP)
50
40
30
20
10
40
50
60
70
80
90
GAS TURBINE -ELECTRIC
Twin Shaft
DDG-X
GEARED GAS TURBINE
Twin Shaft
DD993
ELEC.
FFG-7
GEARED
GAS TURBINE
F
STEAM
Twin Shaft
A
B
C
D
STEAM
E
Single Shaft
A=DD931
D=CG-26
B=DDG2
E=FFG-4
C=CG-16
F=FFG-7

Figure 3-19

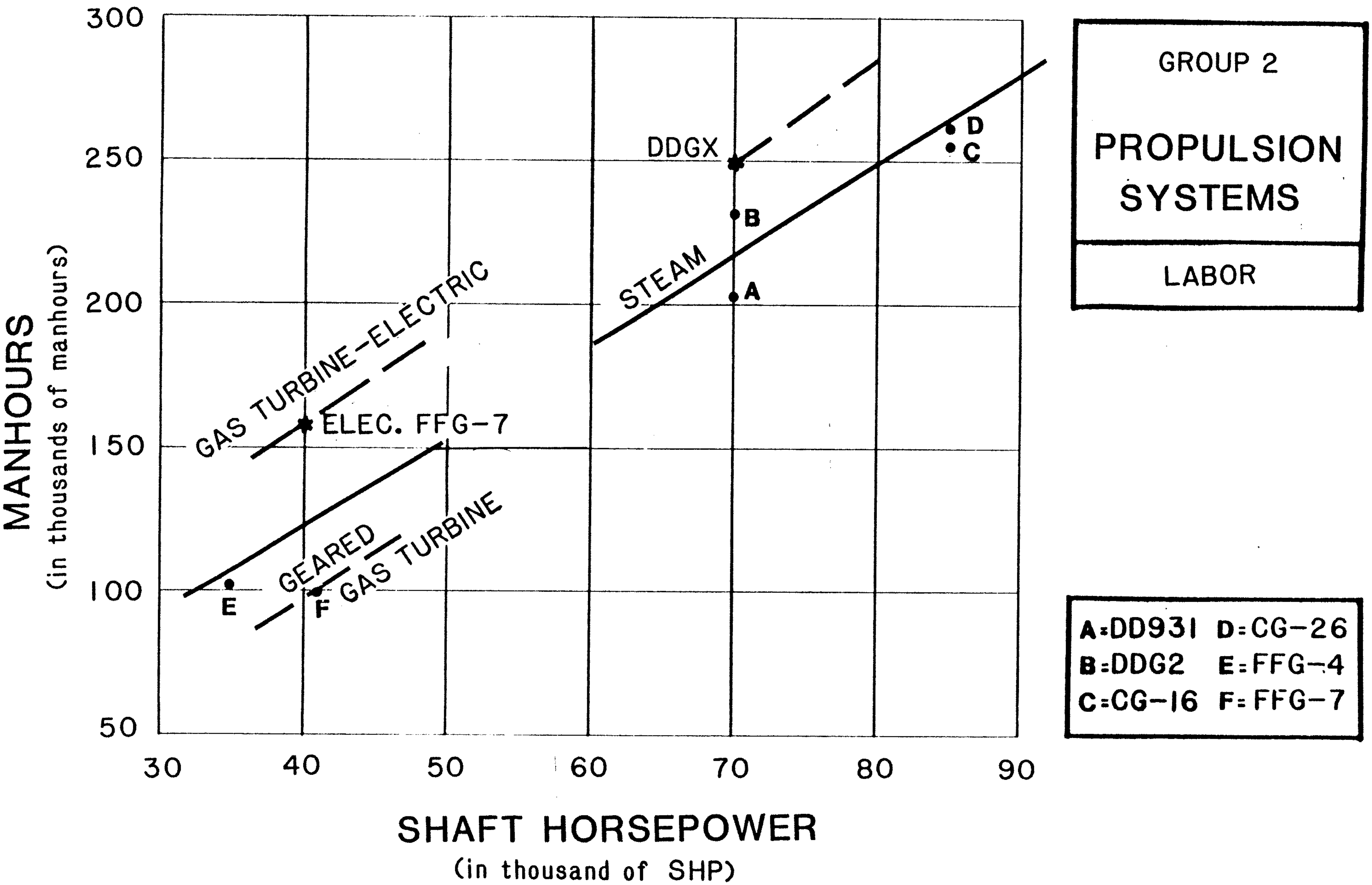

GROUP 2
PROPULSION SYSTEMS
LABOR
MANHOURS
(in thousands of manhours)
SHAFT HORSEPOWER
(in thousand of SHP)
300
250
200
150
100
50
30
40
50
60
70
80
90
DDGX
STEAM
GAS TURBINE-ELECTRIC
ELEC. FFG-7
GEARED
GAS TURBINE
A
B
C
D
E
F
A=DD931 D=CG-26
B=DDG2 E=FFG-4
C=CG-16 F=FFG-7

Figure 3-30

Group 2A - Propulsion Energy System

This group includes propulsion boilers, turbines, reduction gears, feed and condensate system, auxiliary propulsion devices, etc.

MATERIAL COSTS: Propulsion energy system costs depend upon the type, size and number of propulsion systems. Differences between plants are shown by the graphs. The number of prime movers did not seem to impact the curves, which is shown by the proxmity of the FFG-7 to the steam line. Again, the CG-26 was dropped out because it was not a lead design.

The electric propulsion plant as estimated for DDGX is included as a point of reference for new technologies.

CER: \$ = 156 SHP - 446,000
Variable: Shaft horsepower
Application: Steam

CER: \$ = 178 SHP + 214,000
Variable: Shaft horsepower
Application: Geared Gas Turbine

CER: \$ = 208.3 SHP + 16,199
Variable: Shaft horsepower
Application: Electric Gas Turbine

LABOR FACTOR: Man-hours versus shaft horsepower algorithms can be used to estimate labor man-hours.

CER: MH = 1.92 SHP - 18,700
Variable: Shaft horsepower
Application: Steam

CER: MH = 1.30 SHP + 300
Variable: Shaft horsepower
Application: Geared Gas Turbine

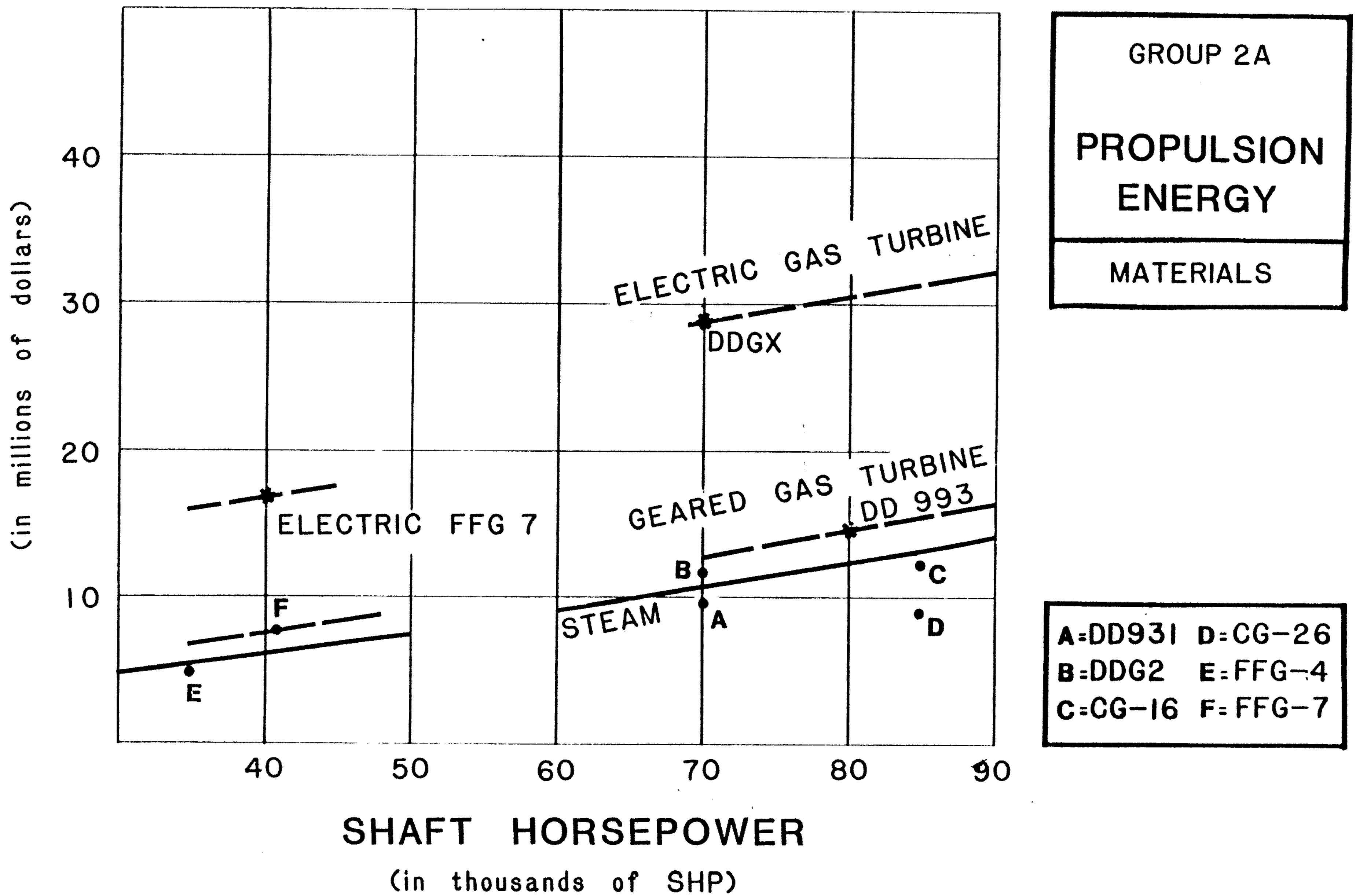
CER: MH = 1.98 SHP + 25,300
Variable: Shaft horsepower
Application: Electric Gas Turbine

See Figures 3-21 and 3-22 for graphs of data points.

Group 2B - Propulsion Train System

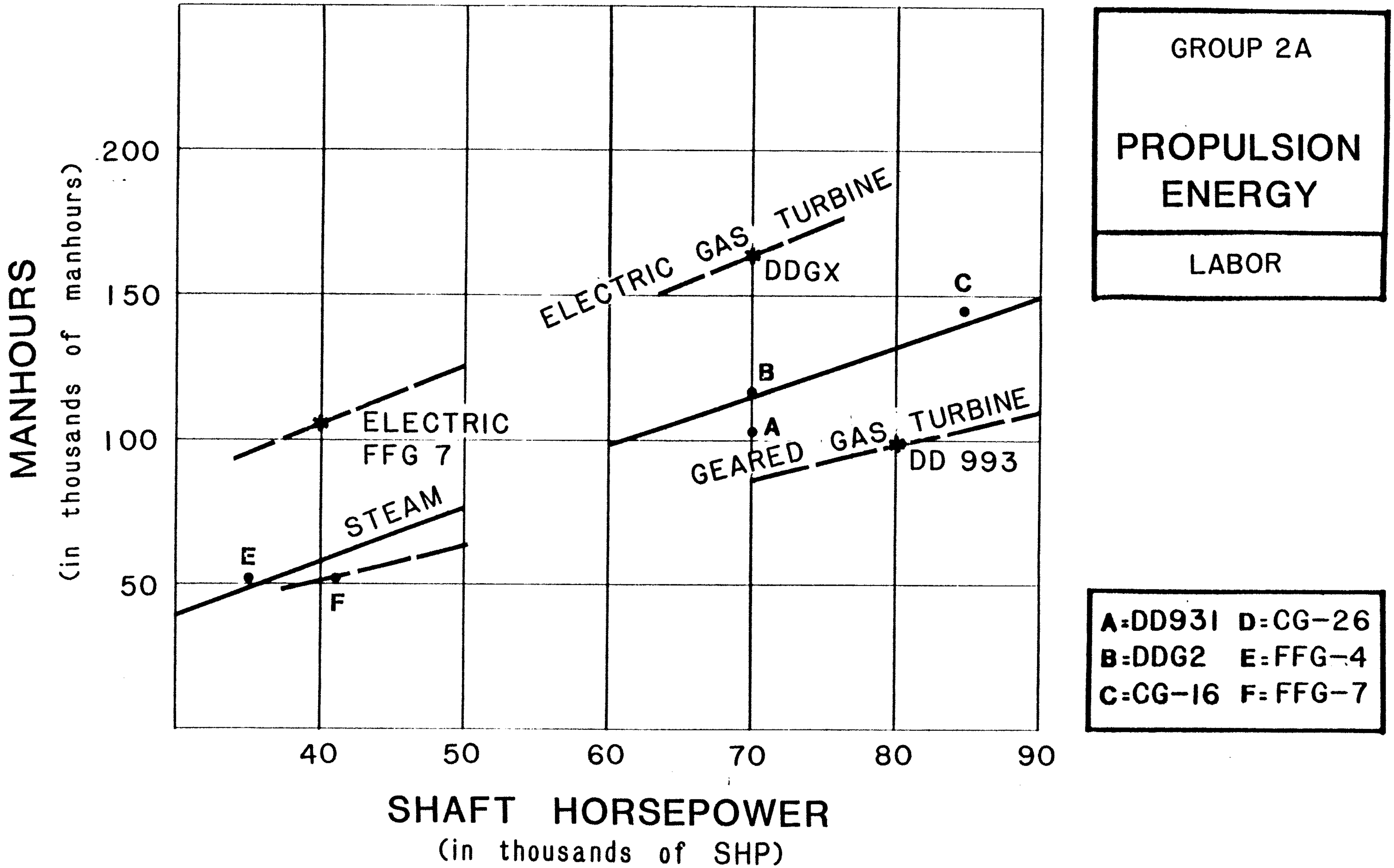
This group includes shafting, shaft bearing, propulsors, etc.

MATERIAL FACTOR: Weight was not chosen for this group because generally a single shaft ship will tend to have a higher specific shaft weight, because they have a higher percentage of outboard shafting. This data base includes two single shaft ships: the FFG-7 and the FFG-4. The FFG-7 has an even higher shaft weight since it was conservatively designed, includes two auxiliary systems, and has the only controllable pitch propeller (which pushes its costs up). The DD-931's shafting is very light because very high strength material was used. The CG-26 and the CG-16 shafting weights are equal, although the 26's torque is significantly higher, which is compensated for by the use of high strength forgings. The FFG-4 correlated fairly well with the other fixed propeller ships; therefore, shaft horsepower was used as the independent variable with two algorithms to differentiate fixed from controllable pitch propellers.



GROUP 2A
PROPULSION ENERGY
MATERIALS
COST
(in millions of dollars)
10
20
30
40
40
50
60
70
80
90
SHAFT HORSEPOWER
(in thousands of SHP)
ELECTRIC GAS TURBINE
DDGX
ELECTRIC FFG 7
GEARED GAS TURBINE
DD 993
STEAM
A
B
C
D
E
F
A=DD931 D=CG-26
B=DDG2 E=FFG-4
C=CG-16 F=FFG-7


Figure 3-21



GROUP 2A
PROPULSION ENERGY
LABOR
MANHOURS
(in thousands of manhours)
SHAFT HORSEPOWER
(in thousands of SHP)
200
150
100
50
40
50
60
70
80
90
ELECTRIC GAS TURBINE
DDGX
ELECTRIC FFG 7
STEAM
GEARED GAS TURBINE
DD 993
A
B
C
E
F
A=DD931 D=CG-26
B=DDG2 E=FFG-4
C=CG-16 F=FFG-7


Figure 3- 22

CER: $ = 11.9 SHP + 112,000
Variable: Shaft horsepower
Application: Fixed Pitch

CER: $ = 46 SHP + 433,000
Variable: Shaft horsepower
Application: Controllable Pitch

LABOR FACTOR: Man-hours versus shaft horsepower (SHP) shows a good correlation.

CER: MH = 0.38 SHP + 6,500
Variable: Shaft horsepower
Application: All

See Figures 3-23 and 3-24 for graphs of data points.

Group 2C - Propulsion Gases System

This group includes the combustion air system, uptakes, etc.

MATERIAL FACTOR: The steam vessels are included in one algorithm and the gas turbine vessels in another. A gas turbine engine like the FFG-7's requires larger ducting for intakes and exhausts. There is a 60 percent increase over that required for a comparable SHP output steam plant. The fact that the CG-26 was not a lead ship lowered it's costs due to a multiple buy. Therefore, the CG-26 was not included in the steam algorithm.

CER: $ = 20.7 SHP - 592,000
Variable: Shaft horsepower
Application: Steam

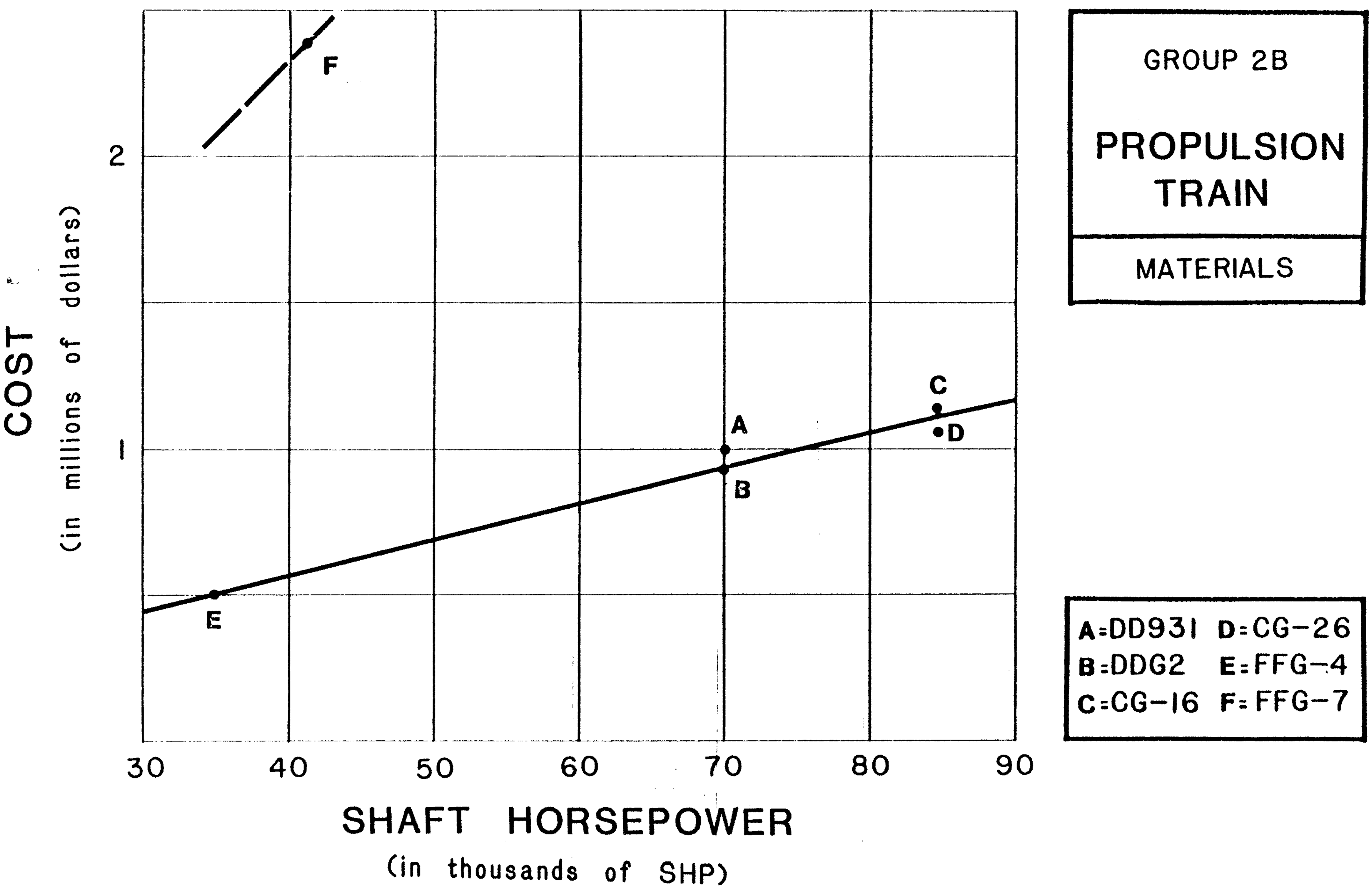

GROUP 2B
PROPULSION TRAIN
MATERIALS
COST
(in millions of dollars)
SHAFT HORSEPOWER
(in thousands of SHP)
2
1
30
40
50
60
70
80
90
A
B
C
D
E
F
A=DD931 D=CG-26
B=DDG2 E=FFG-4
C=CG-16 F=FFG-7

Figure 3- 23

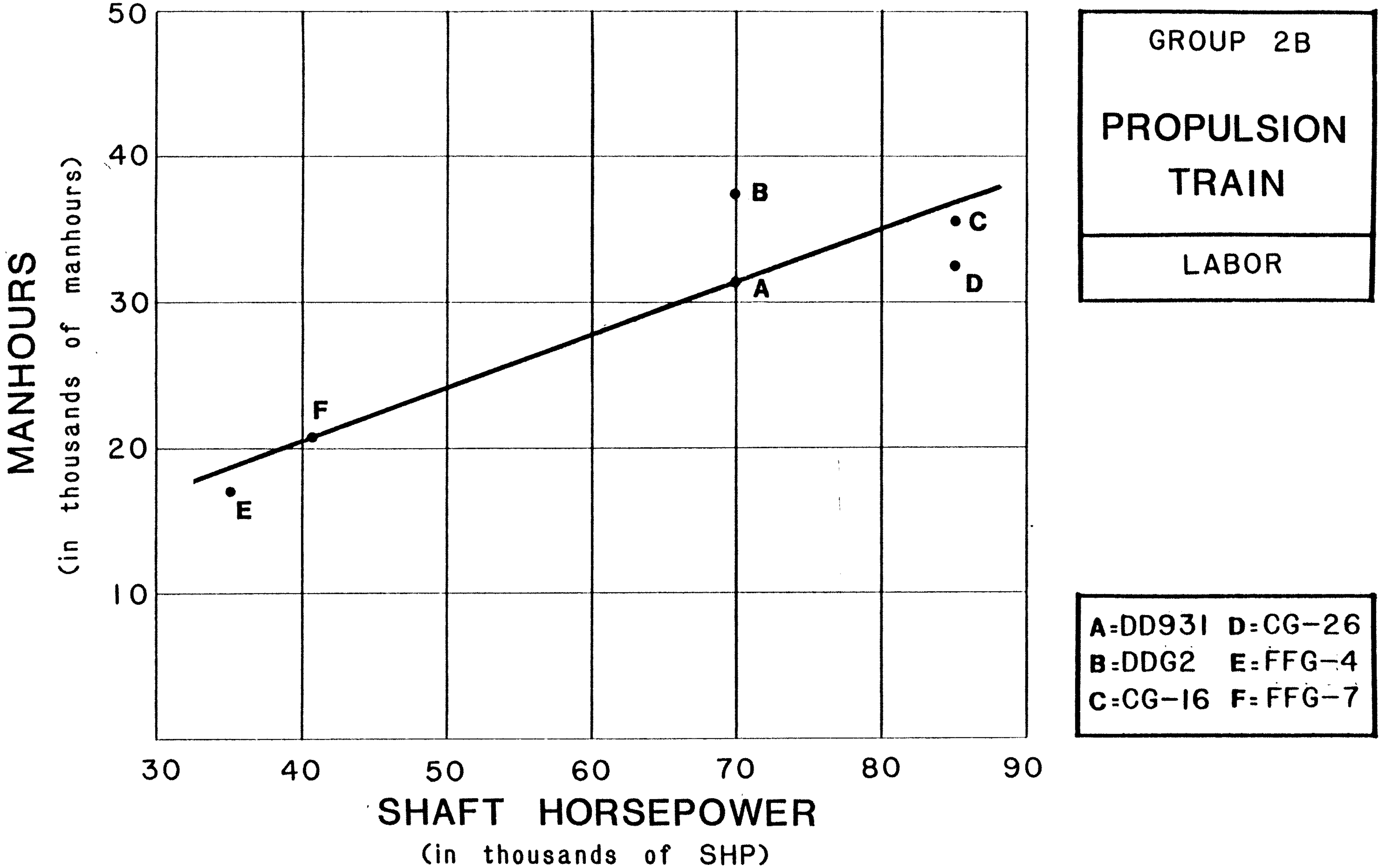

GROUP 2B
PROPULSION TRAIN
LABOR
A=DD931 D=CG-26
B=DDG2 E=FFG-4
C=CG-16 F=FFG-7
MANHOURS
(in thousands of manhours)
SHAFT HORSEPOWER
(in thousands of SHP)
50
40
30
20
10
30
40
50
60
70
80
90
A
B
C
D
E
F

Figure 3-24

CER: $ = 48.2 SHP - 1,378,000
Variable: Shaft horsepower
Application: Gas Turbine

LABOR FACTOR: The man-hours versus shaft horsepower (SHP) showed good correlation.

CER: MH = 0.61 SHP - 13,600
Variable: Shaft horsepower
Application: All

See Figures 3-25 and 3-26 for graphs of data points.

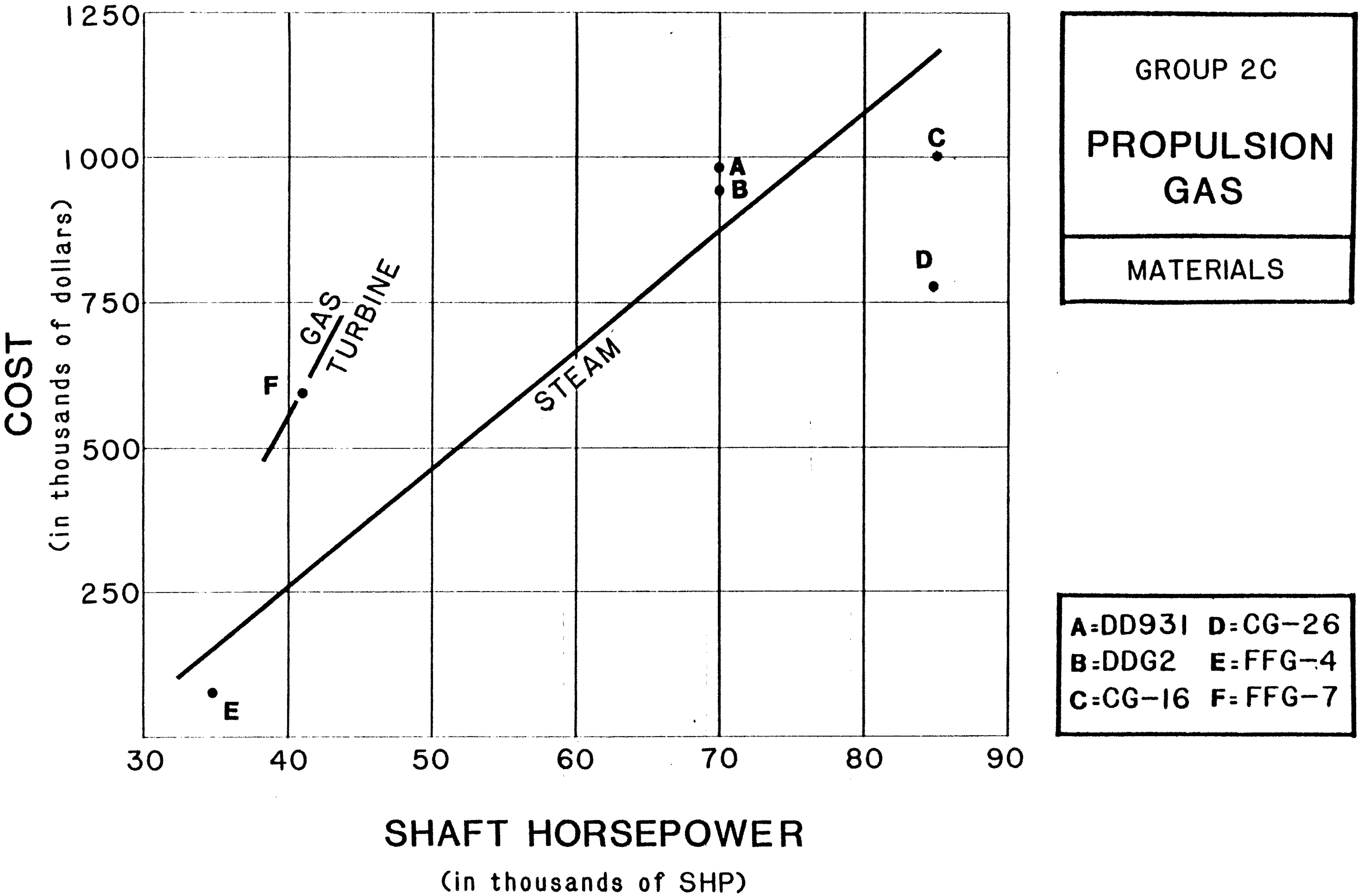
Group 2D - Propulsion Service System

This group includes control systems, seawater circulating and cooling system, H.P. steam drain system, fuel service, and lube oil systems.

MATERIAL FACTOR: The steam powered ships were addressed as one line and the gas turbines with automated controls were another line. The cost versus shaft horsepower graphed best. The gas turbine costs are based on the cost of the FFG-7 alone. Further data will be necessary to confirm this trend line. Actually, subsequent costs may turn out to be less than those found here due to technological improvements.

CER: $ = 10.4 SHP + 148,000
Variable: Shaft horsepower
Application: Steam

CER: $ = 76.9 SHP + 1,093,000
Variable Shaft horsepower
Application: Gas Turbine


GROUP 2C
PROPULSION
GAS
MATERIALS
COST
(in thousands of dollars)
SHAFT HORSEPOWER
(in thousands of SHP)
1250
1000
750
500
250
30
40
50
60
70
80
90
GAS
TURBINE
STEAM
A
B
C
D
E
F
A=DD931 D=CG-26
B=DDG2 E=FFG-4
C=CG-16 F=FFG-7

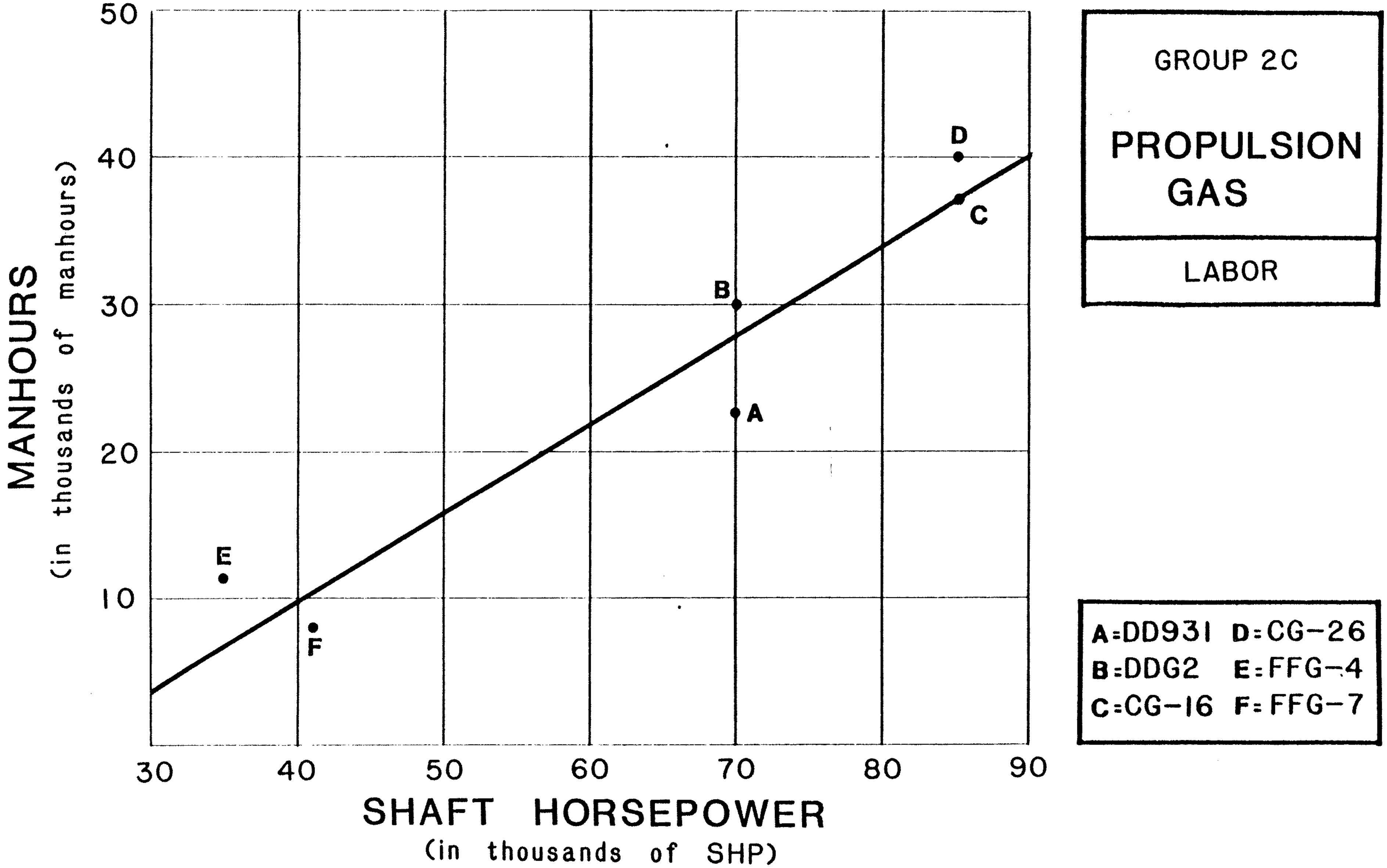

GROUP 2C
PROPULSION GAS
LABOR
MANHOURS
(in thousands of manhours)
SHAFT HORSEPOWER
(in thousands of SHP)
50
40
30
20
10
30
40
50
60
70
80
90
A
B
C
D
E
F
A=DD931 D=CG-26
B=DDG2 E=FFG-4
C=CG-16 F=FFG-7

Figure 3- 26

LABOR FACTOR: Labor costs for all ships correlate very well when graphed against weight instead of SHP.

CER: MH = 543.2 WT - 5,400
Variable: Group 2D Weight
Application: All

See Figures 3-27 and 3-28 for graphs of data points.

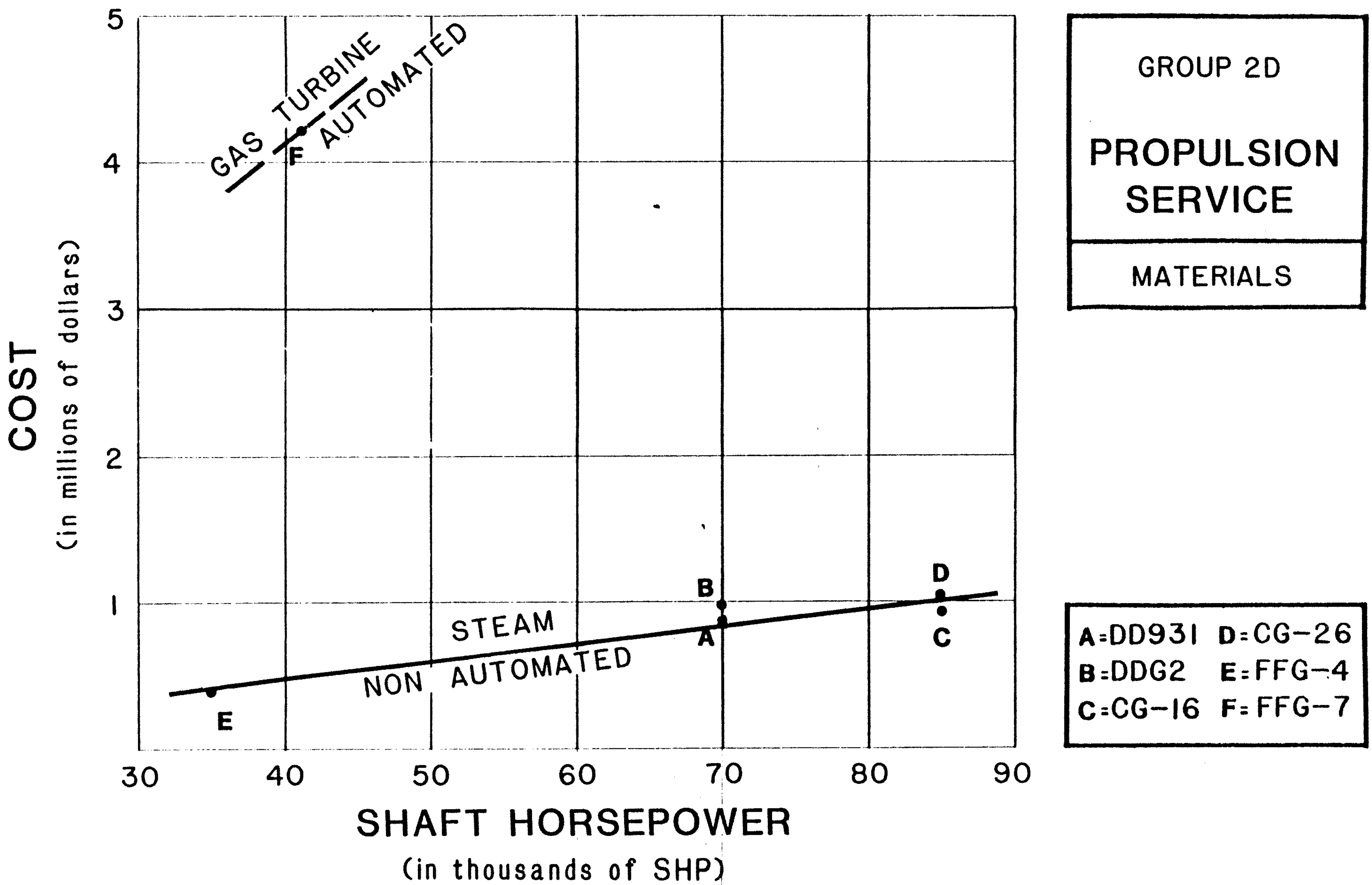
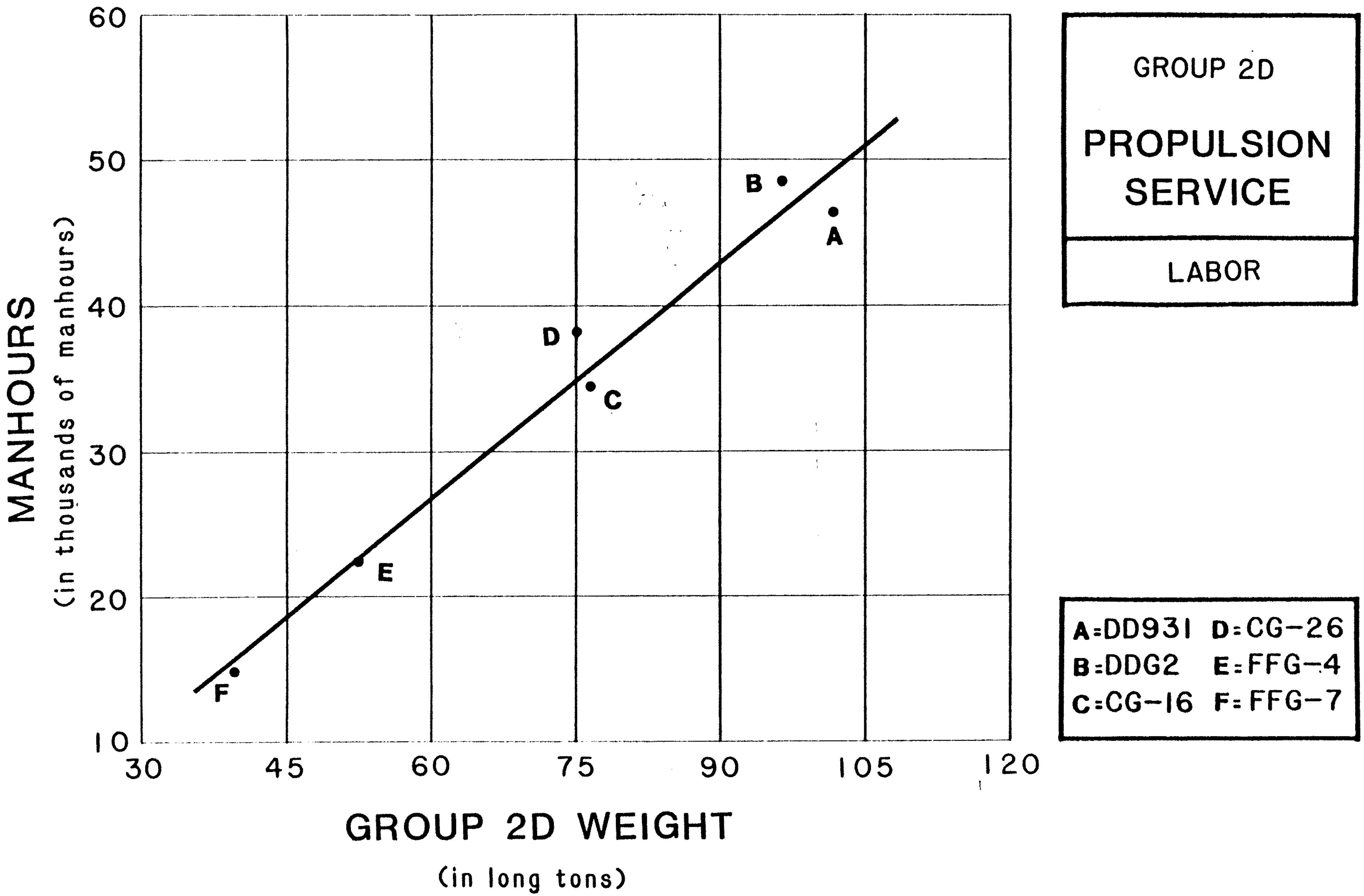

GROUP 2D
PROPULSION SERVICE
MATERIALS
GAS TURBINE
AUTOMATED
STEAM
NON AUTOMATED
A=DD931 D=CG-26
B=DDG2 E=FFG-4
C=CG-16 F=FFG-7
COST
(in millions of dollars)
SHAFT HORSEPOWER
(in thousands of SHP)
A
B
C
D
E
F
1
2
3
4
5
30
40
50
60
70
80
90

Figure 3- 27


GROUP 2D
PROPULSION SERVICE
LABOR
MANHOURS
(in thousands of manhours)
GROUP 2D WEIGHT
(in long tons)
60
50
40
30
20
10
30
45
60
75
90
105
120
A
B
C
D
E
F
A=DD931
B=DDG2
C=CG-16
D=CG-26
E=FFG-4
F=FFG-7

### 3.4.3 Group 3 - Electrical System

3A Electrical Power Generation

3B Electrical Power Distribution

MATERIAL FACTOR: The electrical systems are usually a function of the ship's propulsion system, total installed electric power, and the ship's size. A ship with a steam plant can have a mix of steam turbine or diesel generators, while a geared gas turbine ship will have all diesel generator sets. (The diesel generators costed here were customized for the FFG-7.) Material costs as a function of power installed (kilowatts) can be used to estimate Group 3 costs. Three curves are plotted.

CER: $ = 487 KW + 2,391,000
Variable: Installed kilowatts
Application: Steam generators

CER: $ = 282 KW + 1,382,000
Variable: Installed kilowatts
Application: Steam and Diesel Generators (See explanation, Group 3A)

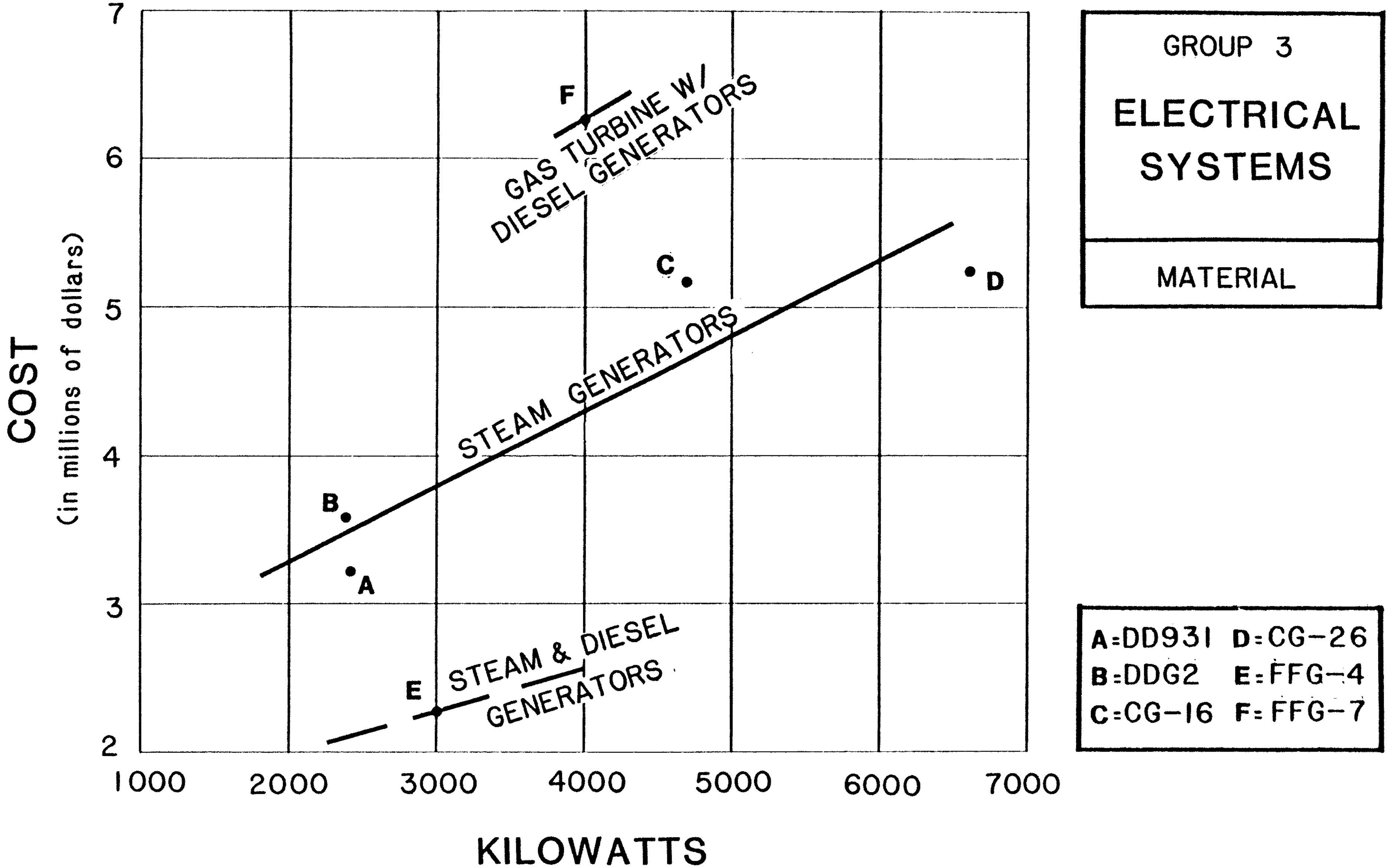
CER: $ = 716 KW + 3,485,000
Variable: Installed kilowatts
Application: Diesel Generators (for GT)

LABOR FACTOR: The graph of man-hours versus weight correlates very well. A separate algorithm is provided for diesel generators.

CER: MH = 1,096 WT - 7,100
Variable: Group 3 Weight
Application: Steam Generators

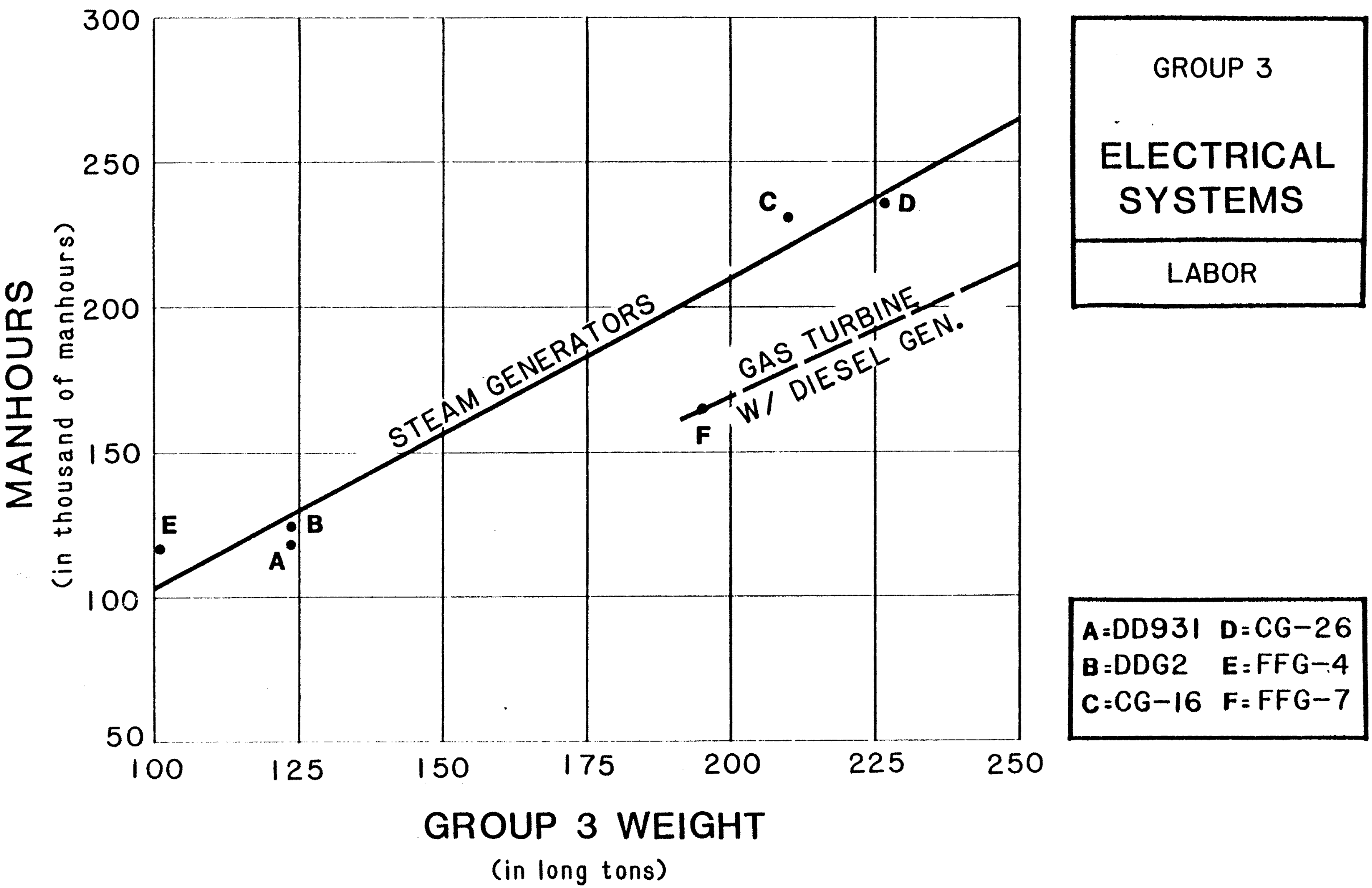
CER: MH = 879 WT - 6,000
Variable: Group 3 Weight
Application: Diesel Generators (for GT)

See Figures 3-29 and 3-30 for graphs of data points.



GAS TURBINE W/ DIESEL GENERATORS
STEAM GENERATORS
STEAM & DIESEL GENERATORS
COST (in millions of dollars)
KILOWATTS
1000
2000
3000
4000
5000
6000
7000
2
3
4
5
6
7
A
B
C
D
E
F
GROUP 3
ELECTRICAL SYSTEMS
MATERIAL
A=DD931 D=CG-26
B=DDG2 E=FFG-4
C=CG-16 F=FFG-7


Figure 3- 29



MANHOURS
(in thousand of manhours)
300
250
200
150
100
50
100
125
150
175
200
225
250
GROUP 3 WEIGHT
(in long tons)
STEAM GENERATORS
GAS TURBINE
W/ DIESEL GEN.
A
B
C
D
E
F
GROUP 3
ELECTRICAL SYSTEMS
LABOR
A=DD931 D=CG-26
B=DDG2 E=FFG-4
C=CG-16 F=FFG-7


Figure 3- 30

Group 3A Electrical Power Generation

This group includes ship service power generation, emergency generators, power conversion equipment, diesel and turbine support systems.

MATERIAL FACTOR: The electrical systems are usually a function of the ship's total installed electric power and the ship's size. The type of propulsion system, which determines which type of generators are to be used, should also be considered. The cost versus installed power is plotted for three combinations: gas turbine propulsion with diesel electric generators, steam propulsion with steam turbine generators, and steam propulsion with steam turbine generators and diesel generators. (Beginning with the FF-1040, there was a major change in design criteria: a separate emergency generator was eliminated and instead, one of the ship's service generators was a diesel.)

CER: $ = 121 KW + 1,909,000
Variable: Installed kilowatts
Application: Steam Generators

CER: $ = 65.8 KW + 1,027,000
Variable: Installed kilowatts
Application: Steam and Diesel Generators

CER: $ = 183 KW + 2,888,000
Variable: Installed kilowatts
Application: Diesel Generators (for G.T.)

LABOR FACTOR: One algorithm is sufficient for Group 3A labor man-hours graphed as a function of the group weight.

CER: MH = 200 WT + 1,600
Variable: Group 3A Weight
Application: All

See Figures 3-31 and 3-32 for graphs of data points.

Group 3B - Electrical Power Distribution

This group includes batteries and service facilities, ship service, emergency and casualty power cable system, switchgear and panels, lighting distribution and fixtures.

MATERIAL FACTORS: The power distribution system depends more upon the ship's size than anything else. It also depends upon the type of switchboards used. Some switchboards are made of aluminum, some of steel. The weights can also vary among the different manufacturers. Later development in circuit technology also has lightened the weight for the newer ships. The correlation of cost versus weight came within 90% even though the data is mixed between aluminum and steel switchboards.

CER: $ = 29,200 WT - 583,000
Variable: Group 3B Weight
Application: All

LABOR FACTOR: In the cases of man-hours versus weight, a single algorithm graphed well. In this instance the FFG-7 and DDG-2 fall below the line (these are the only ships known to have steel switchboards), but this departure does not seem large enough to require a separate algorithm).

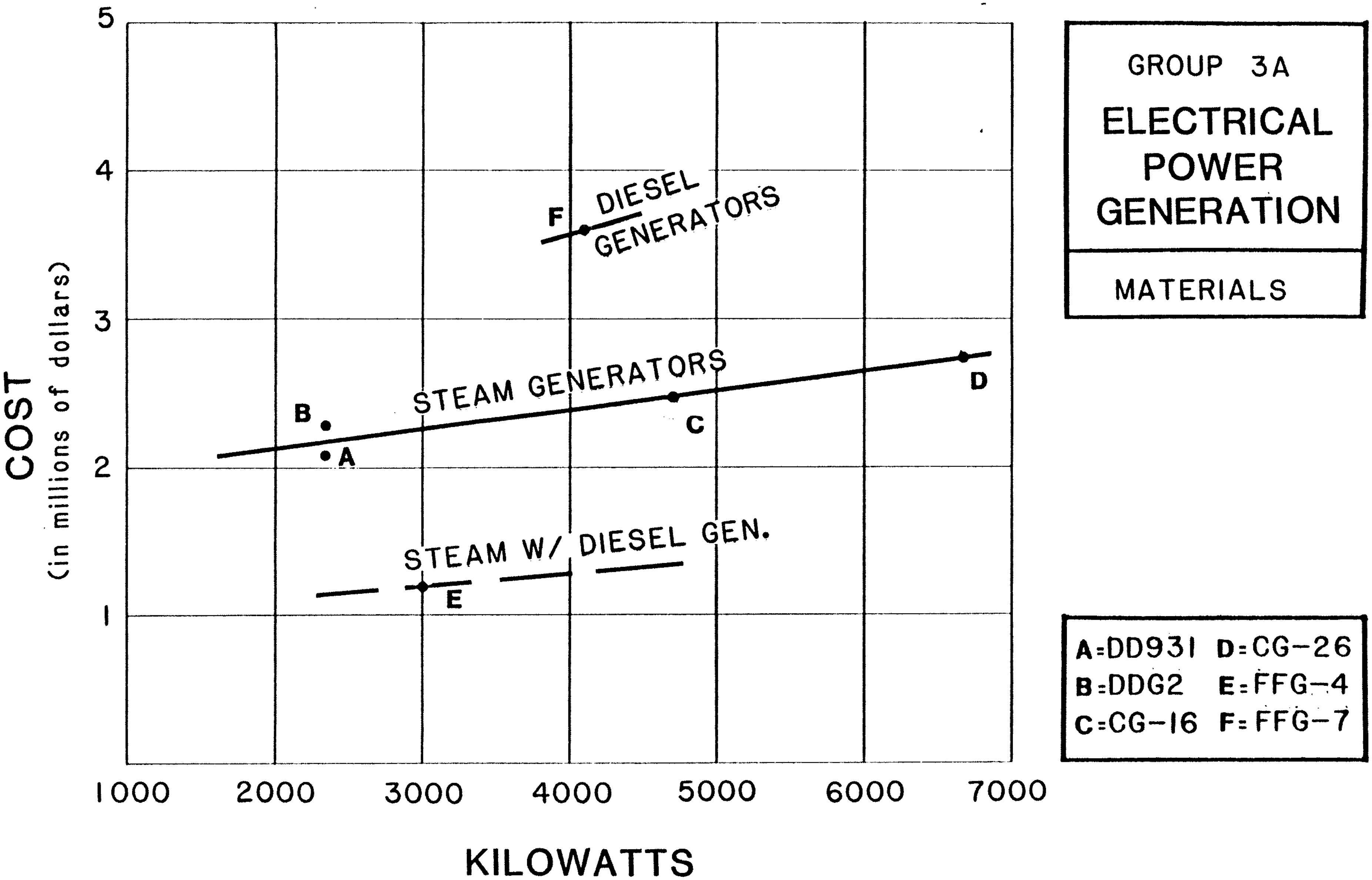

GROUP 3A
ELECTRICAL POWER GENERATION
MATERIALS
COST
(in millions of dollars)
5
4
3
2
1
1000
2000
3000
4000
5000
6000
7000
KILOWATTS
F
DIESEL GENERATORS
STEAM GENERATORS
B
A
C
D
STEAM W/ DIESEL GEN.
E
A=DD931 D=CG-26
B=DDG2 E=FFG-4
C=CG-16 F=FFG-7

Figure 3-31

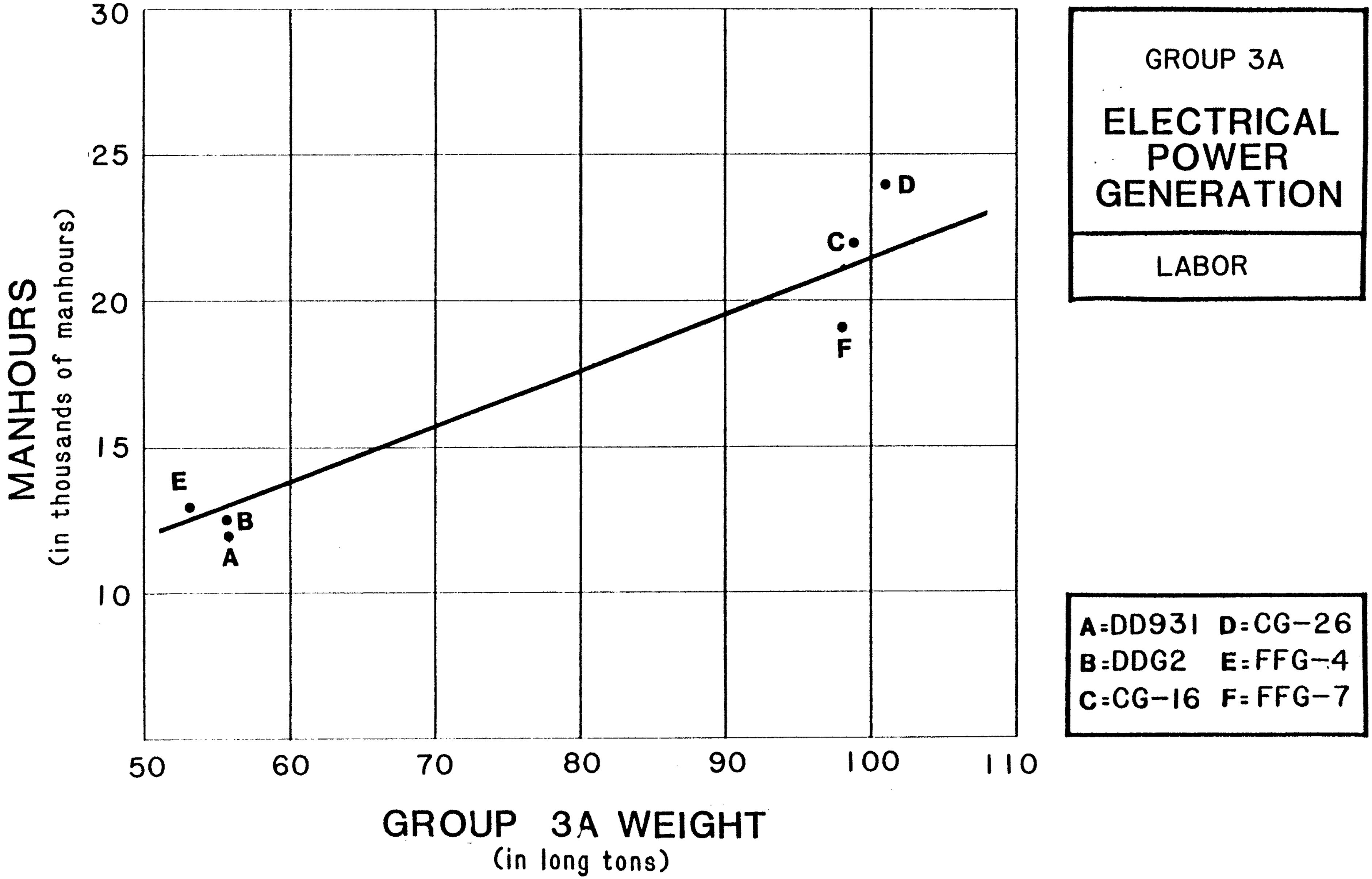

GROUP 3A
ELECTRICAL POWER GENERATION
LABOR
MANHOURS
(in thousands of manhours)
GROUP 3A WEIGHT
(in long tons)
30
25
20
15
10
50
60
70
80
90
100
110
A
B
C
D
E
F
A=DD931 D=CG-26
B=DDG2 E=FFG-4
C=CG-16 F=FFG-7

Figure 3- 32

CER: MH = 1,780 WT - 4,000
Variable: Group 3B Weight
Application: All

See Figures 3-33 and 3-34 for graphs of data points.

3.4.4 Group 4 - Communications and Control

4A Vehicle Command
4B Weapons Command

MATERIAL FACTOR: Material costs are estimated as a function of the Group 4 weight with two algorithms, one for earlier technology systems and one for current technology systems. As will be mentioned in Group 4B, there may be deviations in material costs depending on the systems installed. This does not include the material costs of GFE.

CER: \$ = 1,440 WT + 1,029,000
Variable: Group 4 Weight
Application: Early Technology

CER: \$ = 5,330 WT + 1,920,000
Variable: Group 4 Weight
Application: Current Technology

LABOR FACTOR: Group 4 man-hours may be estimated on the basis of weight with a single algorithm. One consideration for future ships is that as these systems (vehicle command and weapons command) become more sophisticated current trends indicate that they will become more modular requiring less labor for installation. The FFG-7 is one example of this trend.

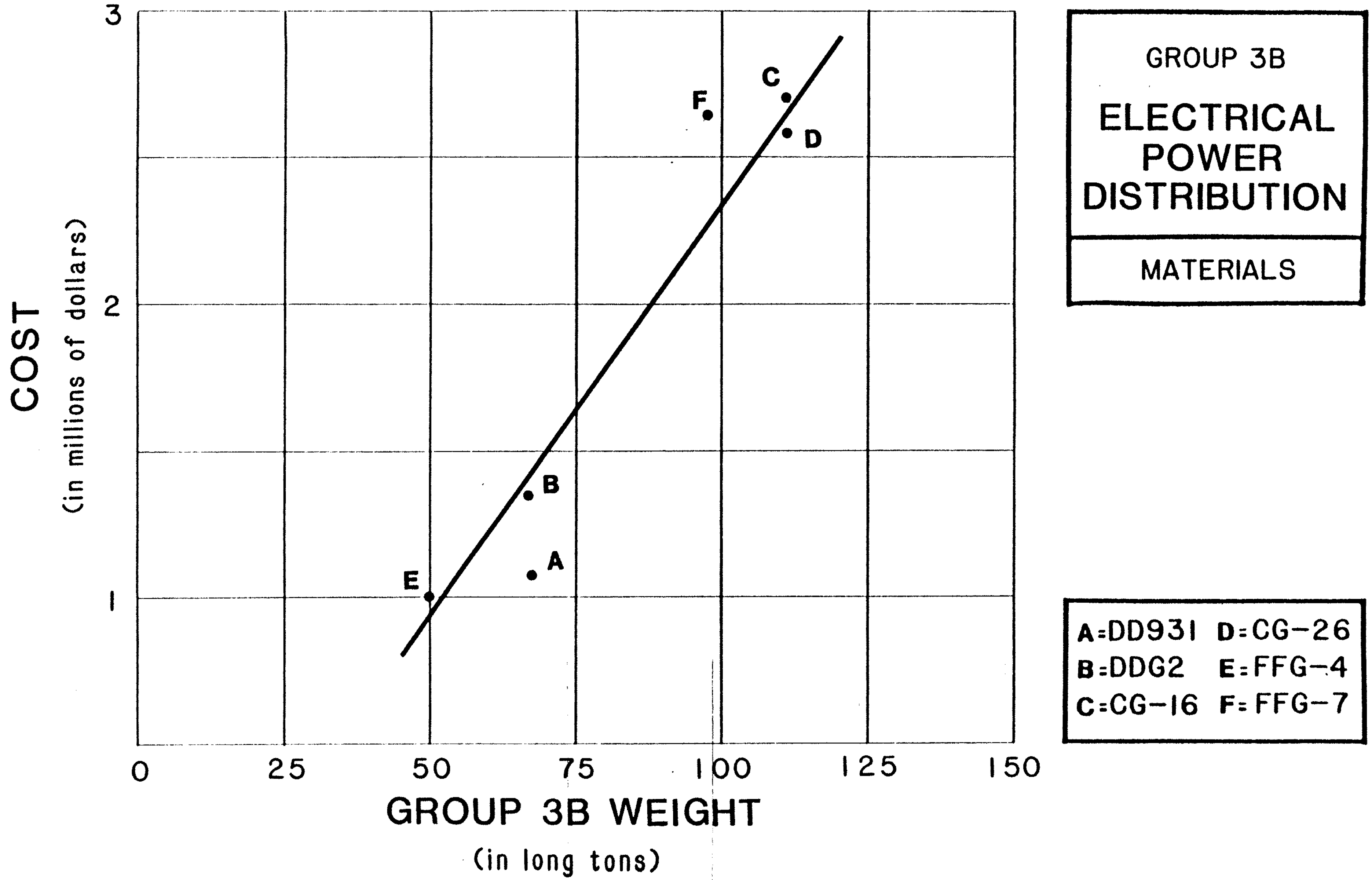

GROUP 3B
ELECTRICAL POWER DISTRIBUTION
MATERIALS
COST
(in millions of dollars)
3
2
1
0
25
50
75
100
125
150
GROUP 3B WEIGHT
(in long tons)
A
B
C
D
E
F
A=DD931 D=CG-26
B=DDG2 E=FFG-4
C=CG-16 F=FFG-7

Figure 3-33

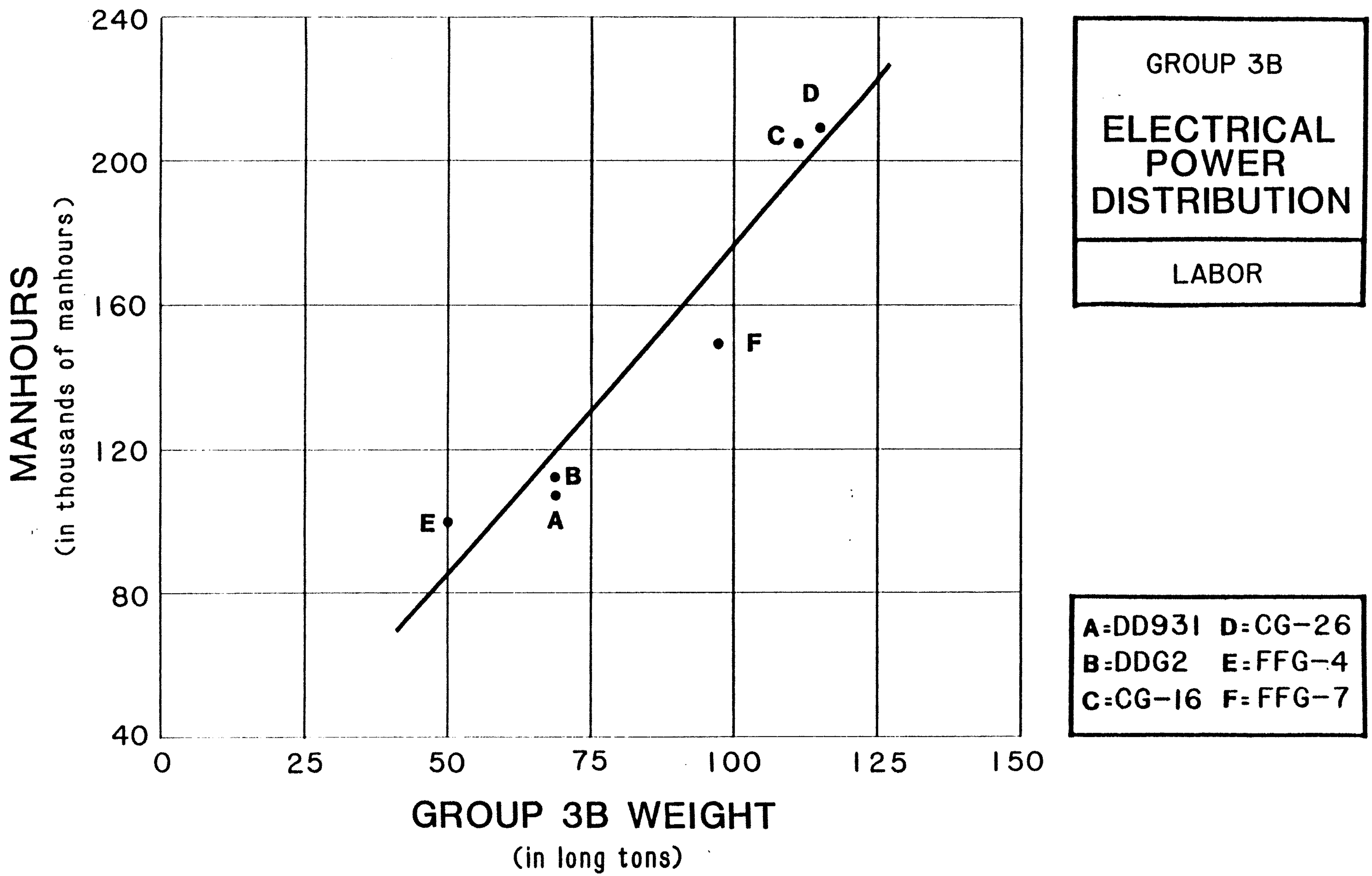

240
200
160
120
80
40
0
25
50
75
100
125
150
MANHOURS
(in thousands of manhours)
GROUP 3B WEIGHT
(in long tons)
A
B
C
D
E
F
GROUP 3B
ELECTRICAL POWER DISTRIBUTION
LABOR
A=DD931 D=CG-26
B=DDG2 E=FFG-4
C=CG-16 F=FFG-7

Figure 3-34

CER: MH = 513 WT + 34,700
Variable: Group 4 Weight
Application: All

See Figures 3-35 and 3-36 for graphs of data points.

Group 4A - Vehicle Command

This group includes navigation equipment, interior communication, and countermeasures systems, such as degaussing.

MATERIAL FACTOR: Material costs for Group 4A as a function of weight fall into two groups. The two algorithms represent a change over time in the sophistication of equipment and the use of lighter weight non-armored cable for interior communications. The 1955 to 1965 vintage destroyers generally used armored cable and only very crude data processing with no satellite communication. The present day and future ships would probably follow the non-armored cable line.

CER: $ = 3,830 WT + 591,000
Variable: Group 4A Weight
Application: Early Technology

CER: $ = 6,180 WT + 997,000
Variable: Group 4A Weight
Application: Current Technology

LABOR FACTOR: Group 4A man-hours can be estimated as a function of weight with no variation for technology changes as yet. Labor man-hours for

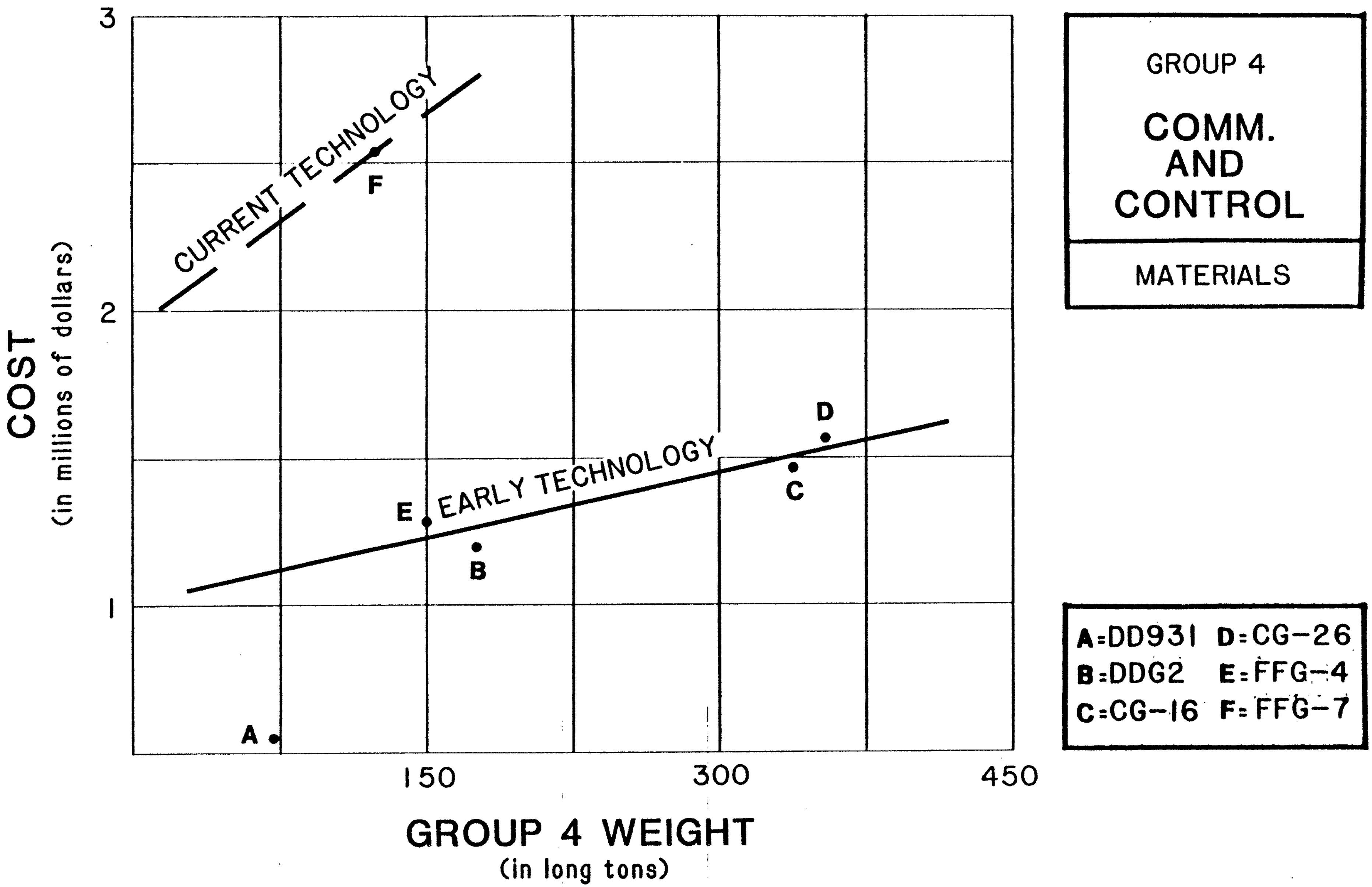

3
2
1
COST
(in millions of dollars)
CURRENT TECHNOLOGY
F
EARLY TECHNOLOGY
A
B
C
D
E
150
300
450
GROUP 4 WEIGHT
(in long tons)
GROUP 4
COMM. AND CONTROL
MATERIALS
A=DD931 D=CG-26
B=DDG2 E=FFG-4
C=CG-16 F=FFG-7

Figure 3-35

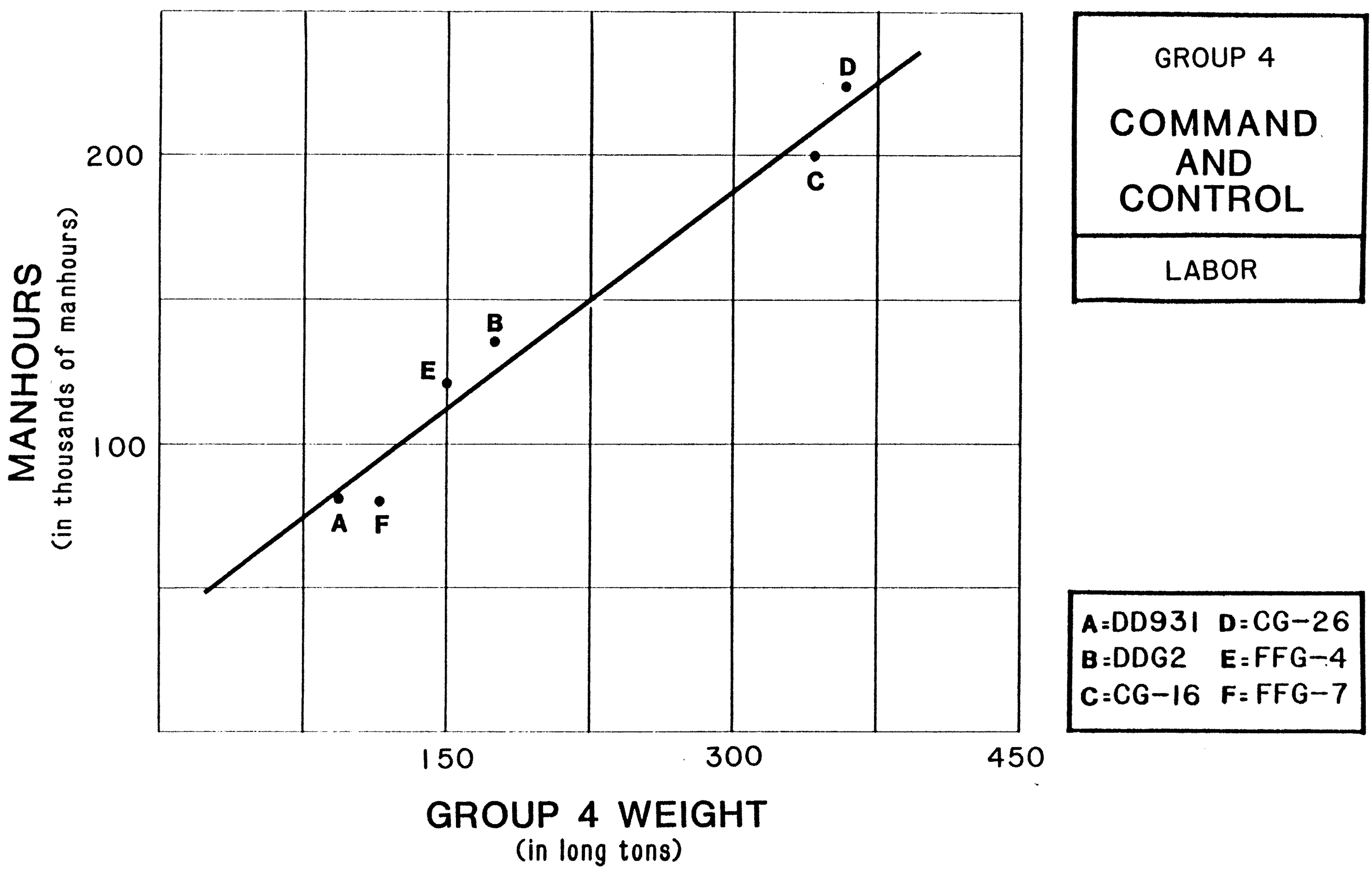

GROUP 4
COMMAND AND CONTROL
LABOR
A=DD931 D=CG-26
B=DDG2 E=FFG-4
C=CG-16 F=FFG-7
MANHOURS
(in thousands of manhours)
200
100
150
300
450
GROUP 4 WEIGHT
(in long tons)
A
B
C
D
E
F

Figure 3-36

future technology systems should decrease with increasing modularization of the systems.

CER: MH = 1,010 WT - 8,700
Variable: Group 4A Weight
Application: All

See Figures 3-37 and 3-38 for graphs of data points.

Group 4B Weapons Command

This group includes only installation costs for fire control systems, electronic countermeasures, radar and sonar systems. (The installed system's acquisition costs are not included in this model.)

MATERIAL FACTOR: Communication, sensor and weapon contol items are essentially independent of the ship's size or weight parameters. In many cases they represent the ship's mission or its reason for existence. For this programming quality cost estimate, this group's installation costs can be estimated based on the appropriate technology line as a function of weight. Group costs may vary because they include highly specialized equipment usually chosen for certain weapons systems or combinations thereof.

CER: 1,740 WT + 194,000
Variable: Group 4B Weight
Application: Early Technology

CER: \$ = 6,910 WT + 768,000
Variable: Group 4B Weight
Application: Current Technology

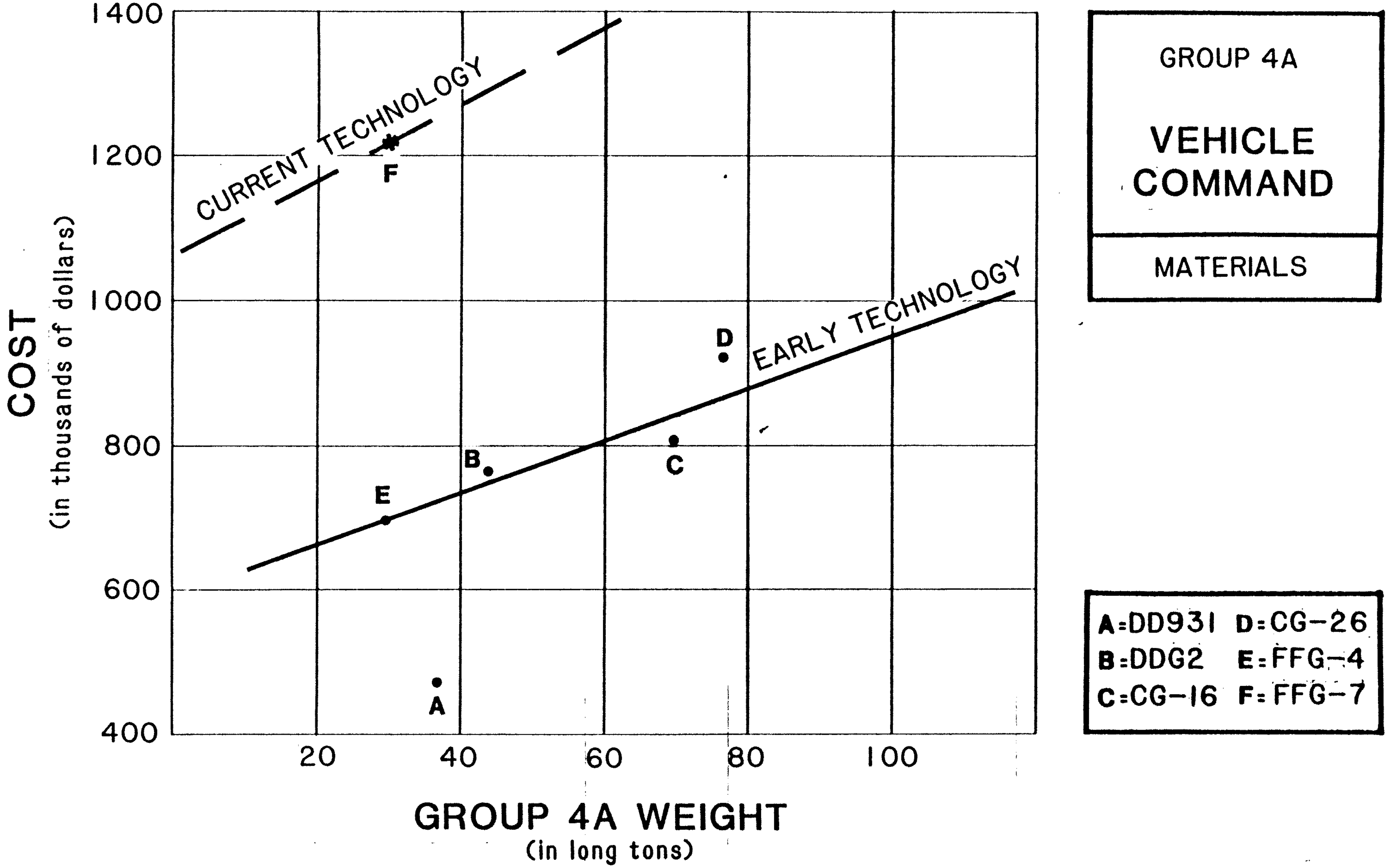

COST
(in thousands of dollars)
1400
1200
1000
800
600
400
20
40
60
80
100
GROUP 4A WEIGHT
(in long tons)
CURRENT TECHNOLOGY
EARLY TECHNOLOGY
A
B
C
D
E
F
GROUP 4A
VEHICLE COMMAND
MATERIALS
A=DD931 D=CG-26
B=DDG2 E=FFG-4
C=CG-16 F=FFG-7

Figure 3-37

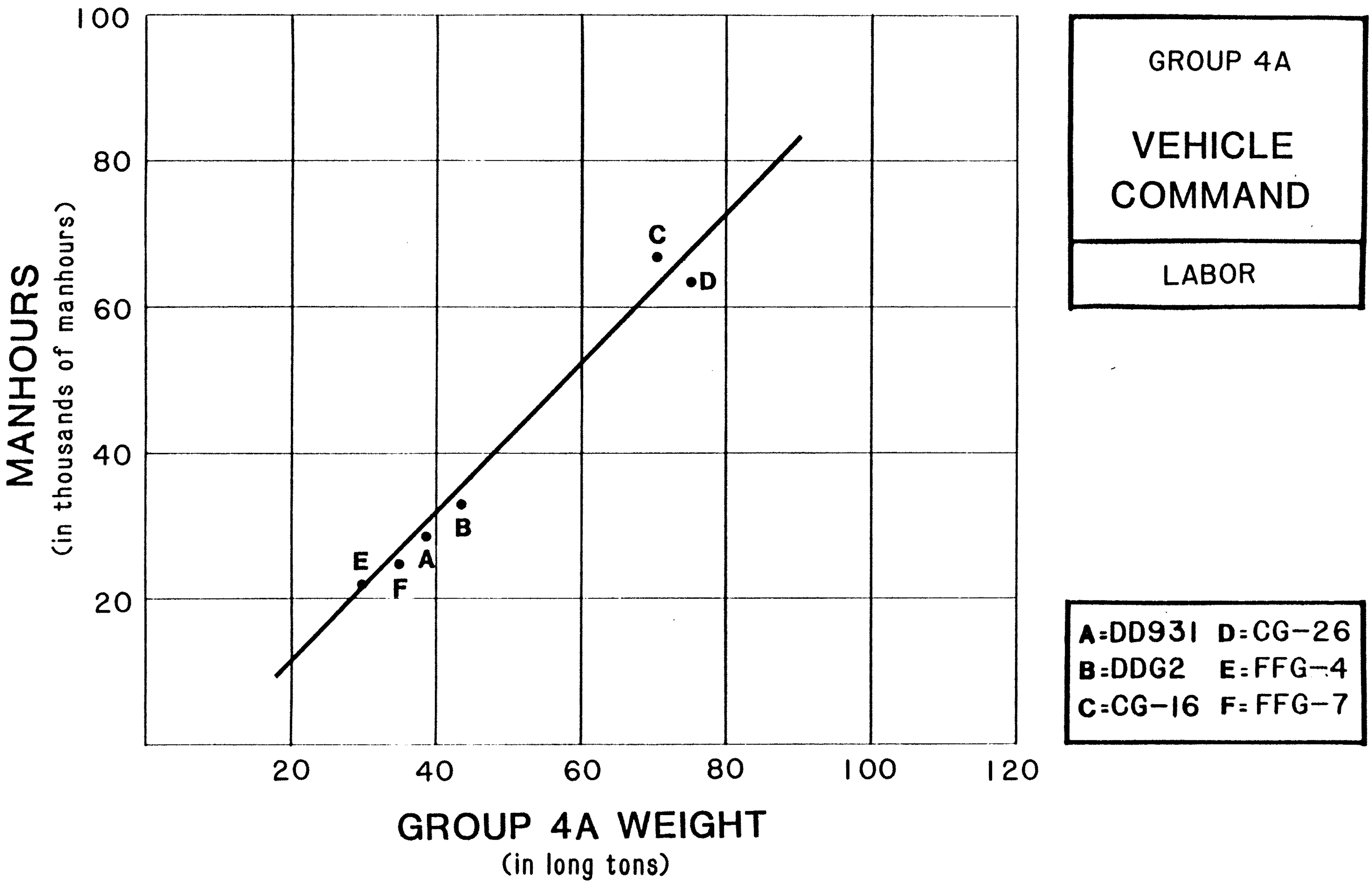

100
80
60
40
20
MANHOURS
(in thousands of manhours)
20
40
60
80
100
120
GROUP 4A WEIGHT
(in long tons)
C
D
B
A
E
F
GROUP 4A
VEHICLE COMMAND
LABOR
A=DD931 D=CG-26
B=DDG2 E=FFG-4
C=CG-16 F=FFG-7

Figure 3-38

LABOR FACTOR: Group 4B man-hours can be estimated based upon the group weight. The choice of weapons command equipment does not radically affect the man-hours involved. As systems become more capable and complex, they also become easier to install (modular components, pre made-up wiring with quick connectors, etc.)

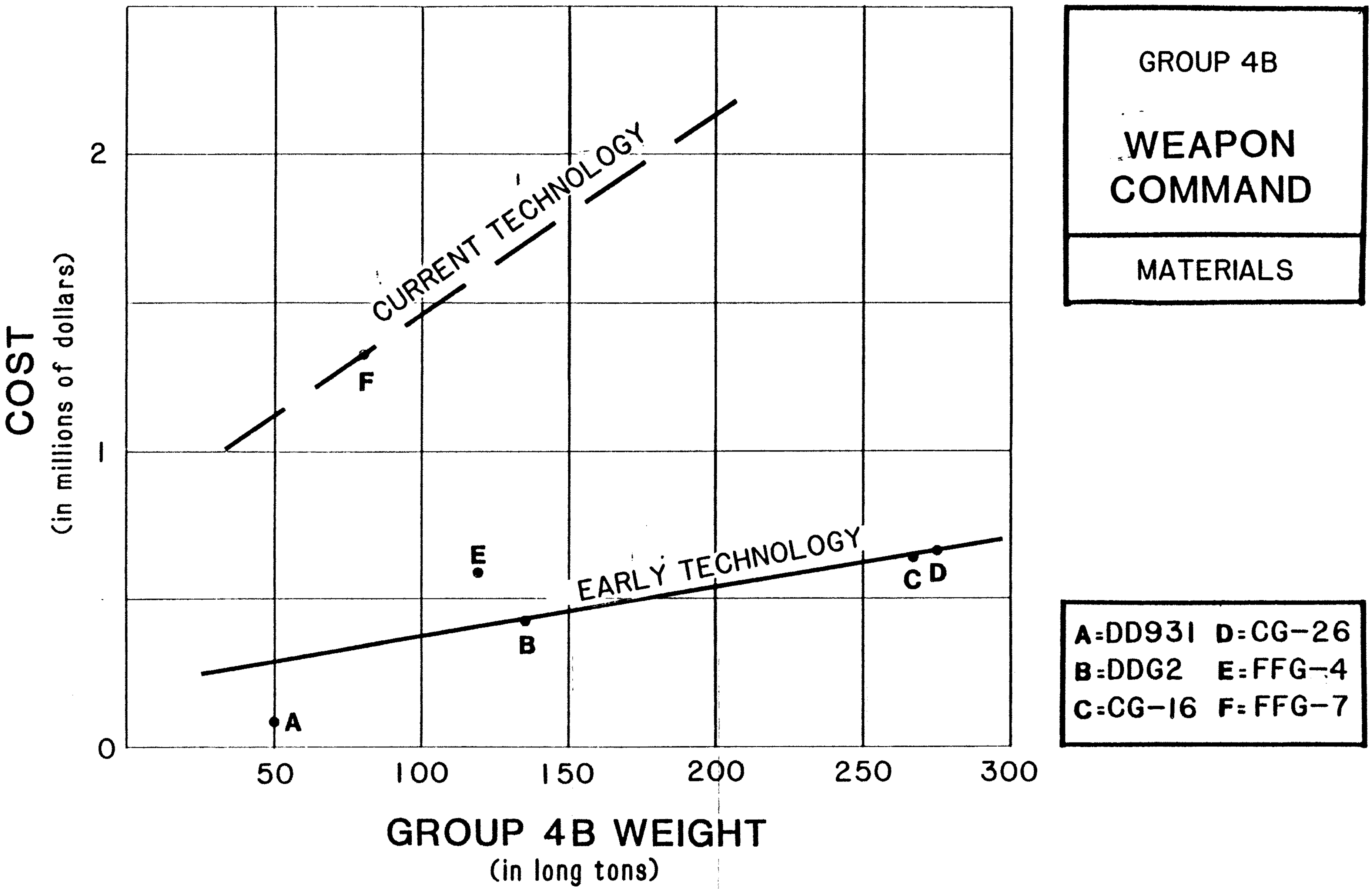
CER: MH = 416 WT + 34,300
Variable: Group 4B Weight
Application: All

See Figures 3-39 and 3-40 for graphs of data points.

### 3.4.5 Group 5 - Auxiliary Systems

5A Environment
5B Fluid Systems
5C Maneuvering
5D Handling

MATERIAL FACTOR: At the one-digit level, weight is used as the independent variable for Group 5. For material costs, there are two algorithms, one for electric heat, "missile" ships and one for steam heat, "non-missile" ships. As has been recorded for the two-digit Group 5 costs, there are several options that could not be costed out. The electric heat "missile" line reflects the newer habitability standards for heat and air conditioning, single missile magazine flooding requirements and a clean ballast system. The steam line reflects the pre-1965



GROUP 4B
WEAPON COMMAND
MATERIALS
COST (in millions of dollars)
2
1
0
50
100
150
200
250
300
GROUP 4B WEIGHT (in long tons)
CURRENT TECHNOLOGY
EARLY TECHNOLOGY
A
B
C
D
E
F
A=DD931 D=CG-26
B=DDG2 E=FFG-4
C=CG-16 F=FFG-7


Figure 3-39

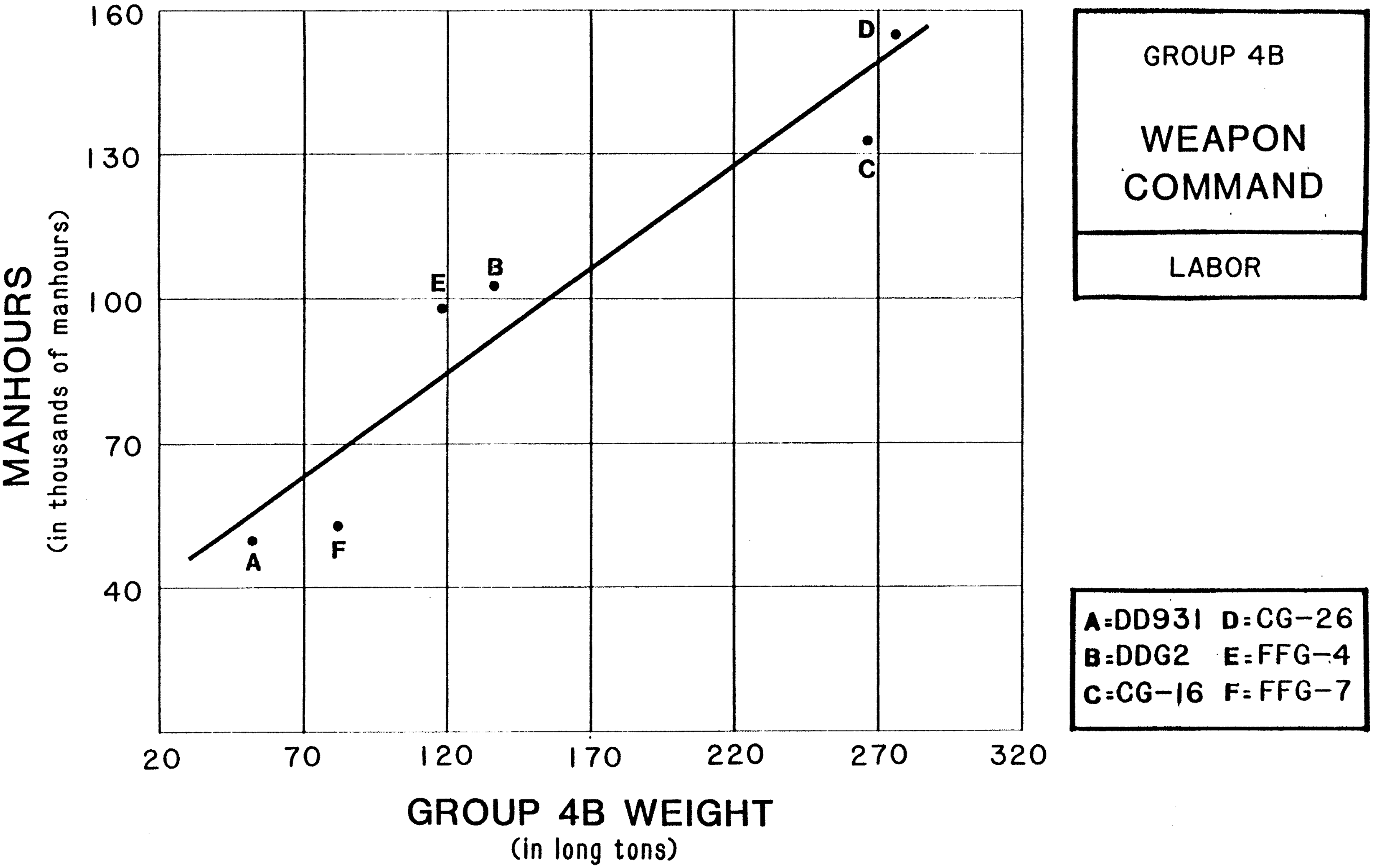

GROUP 4B
WEAPON COMMAND
LABOR
MANHOURS
(in thousands of manhours)
GROUP 4B WEIGHT
(in long tons)
160
130
100
70
40
20
70
120
170
220
270
320
A
B
C
D
E
F
A=DD931 D=CG-26
B=DDG2 E=FFG-4
C=CG-16 F=FFG-7

Figure 3-40

habitability standards and no missile considerations.

CER: $ = 6,730 WT + 1,023,000
Variable: Group 5 Weight
Application: Steam Heat, "Non-Missile"

CER: $ = 17,200 WT + 2,604,000
Variable: Group 5 Weight
Application: Electric Heat, "Missile"

LABOR FACTOR: Group 5 labor figures can be estimated best as a function of weight. An algorithm for electric heat and one for steam heat are plotted. In almost all of Group 5, the learning curve effect can be seen in CG-26 since it followed CG-16 at the same yard and has basically the same systems.

CER: MH = 1,150 WT - 59,400
Variable: Group 5 Weight
Application: Steam Heat, "Non-Missile"

CER: MH = 780 WT - 40,300
Variable: Group 5 Weight
Application: Electric Heat, "Missile"

See Figures 3-41 and 3-42 for graphs of data points.

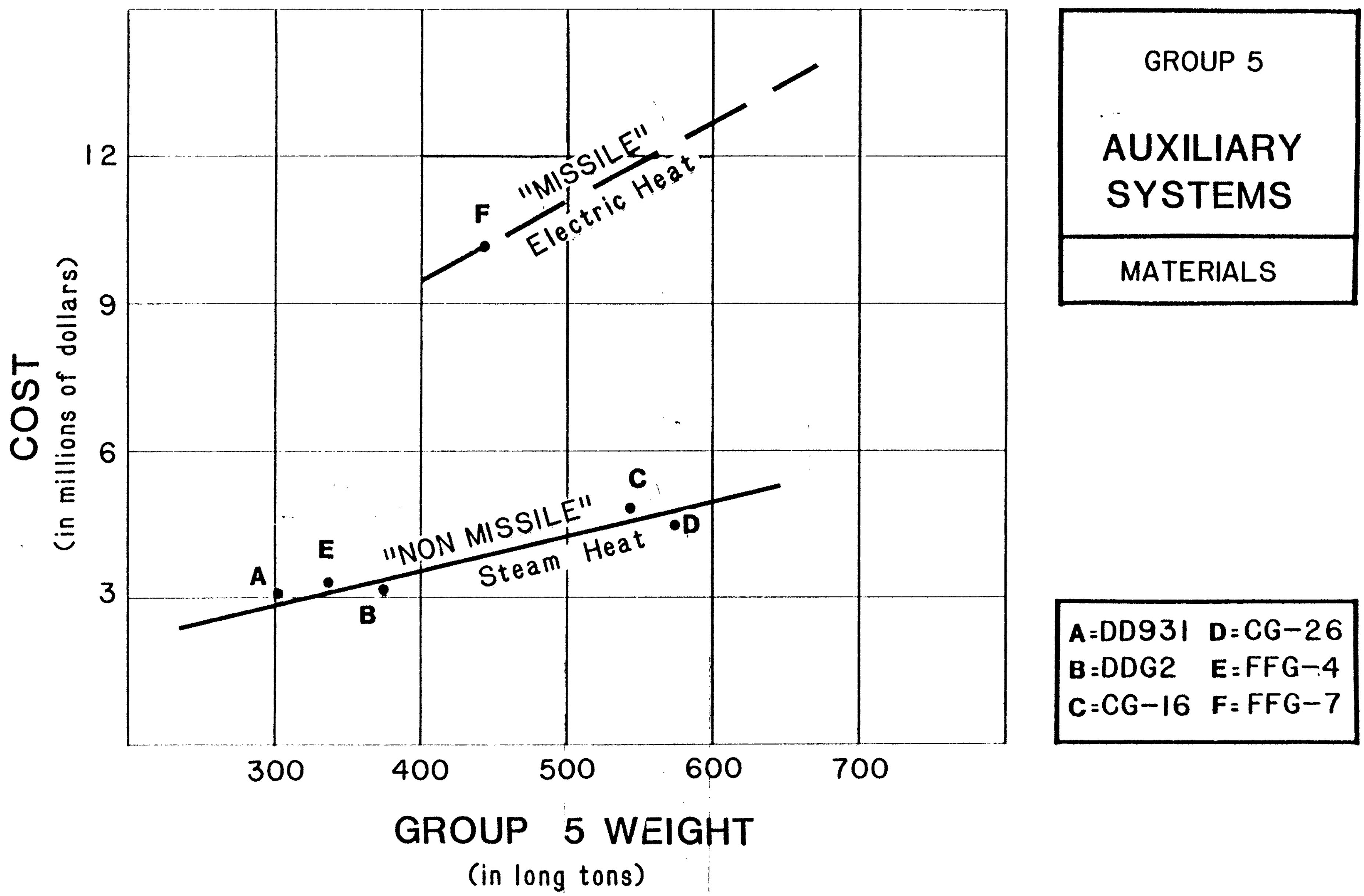

GROUP 5
AUXILIARY SYSTEMS
MATERIALS
COST
(in millions of dollars)
12
9
6
3
300
400
500
600
700
GROUP 5 WEIGHT
(in long tons)
"MISSILE"
Electric Heat
"NON MISSILE"
Steam Heat
A
B
C
D
E
F
A=DD931 D=CG-26
B=DDG2 E=FFG-4
C=CG-16 F=FFG-7

Figure 3-41

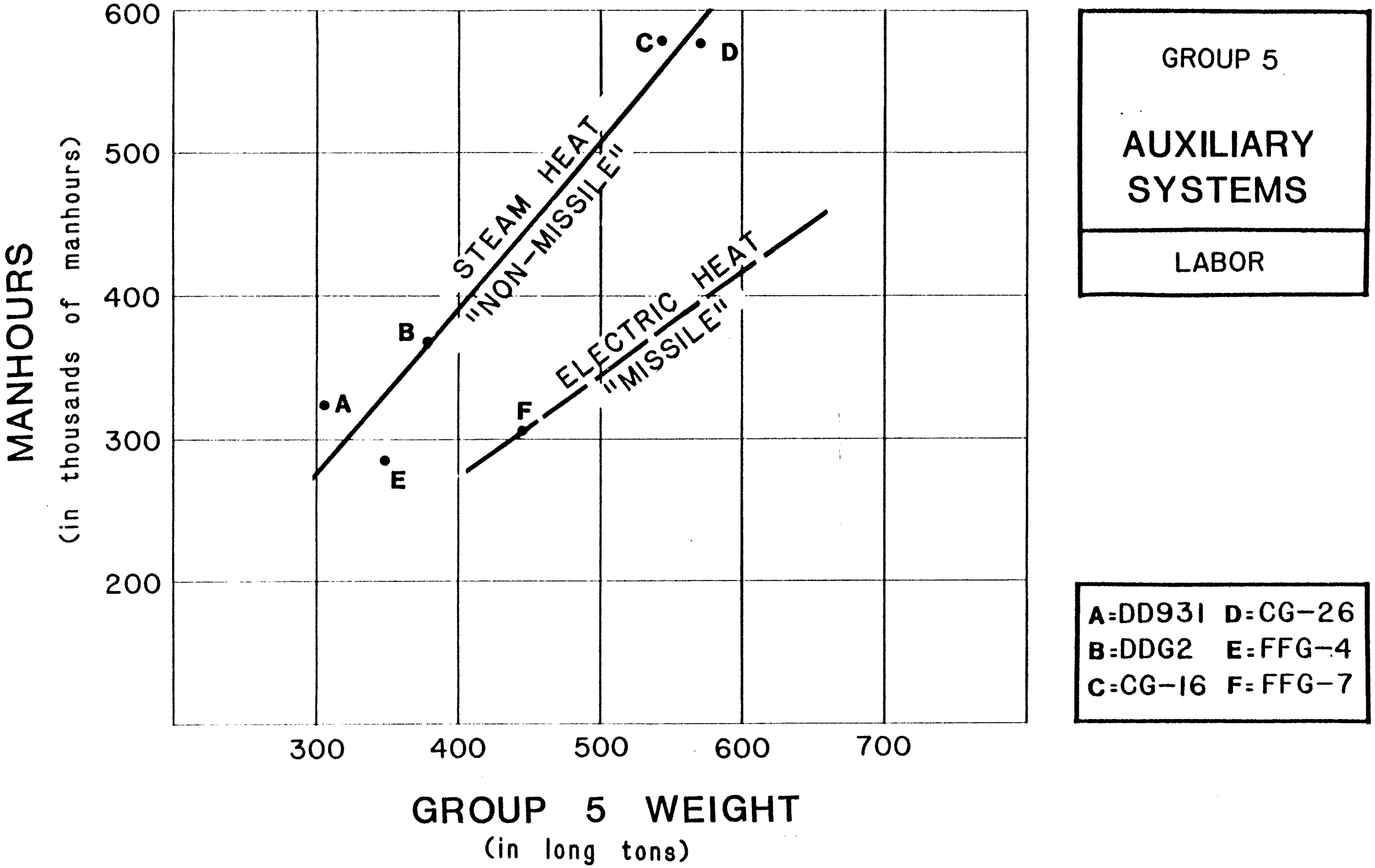

600
500
400
300
200
MANHOURS
(in thousands of manhours)
300
400
500
600
700
GROUP 5 WEIGHT
(in long tons)
STEAM HEAT
"NON-MISSILE"
ELECTRIC HEAT
"MISSILE"
A
B
C
D
E
F
GROUP 5
AUXILIARY SYSTEMS
LABOR
A=DD931 D=CG-26
B=DDG2 E=FFG-4
C=CG-16 F=FFG-7

Figure 3-42

Group 5A - Environment

This group includes the heating, ventilation and air conditioning systems plus the refrigerated spaces.

MATERIAL FACTOR: Several parameters were examined for Group 5A, and two show good correlation with 5A costs. Group 5A material costs as a function of weight fall into two categories: steam heat systems and electric heat systems. One factor that could not be broken out is the effect of habitability standards on the data. The FFG-7 (electric) data is based upon the environmental control standards requiring a 80°/70°F range while the other ships (all steam) are based on the more austere standards, 85°/65°F.

CER: $ = 9,060 WT + 64,000
Variable: Group 5A Weight
Application: Steam Heat

CER: $ = 18,900 WT + 152,000
Variable: Group 5A Weight
Application: Electric Heat

LABOR FACTOR: The man-hours for Group 5A as a function of weight fall into the same two major categories: steam heat systems and electric systems.

CER: MH = 1,430 WT + 27,600
Variable: Group 5A Weight
Application: Steam Heat

CER: MH = 938 WT + 14,500
Variable: Group 5A Weight
Application: Electric Heat

See Figures 3-43 and 3-44 for graphs of data points.

Group 5B <u>Fluid Systems</u>

This group includes plumbing, firemain, drainage, ballast, freshwater, steam, compressed air and fuel systems.

MATERIAL FACTOR: While the components of Group 5B are functions of several different ship parameters, such as ship size (firemain), length x beam (L x B) (drainage and ballast), complement (plumbing and freshwater), aircraft (fuel), and others, the group cost as a function of weight graphed with good correlation of the data points. The "non-missile" algorithm plotted represents only steam vessels with pre-1965 habitability standards for plumbing and freshwater systems. Of these the FFG-4 has Prairie Masker while the rest do not and the CG 26 and FFG 4 have one helicopter, which requires an additional fuel system on board. These differences do not seem to make a marked difference when the cost is derived as a function of the group weight. The "missile" algorithm represents the only gas turbine vessel (no steam auxiliary system) with two helos, prairie masker and a "clean" ballast

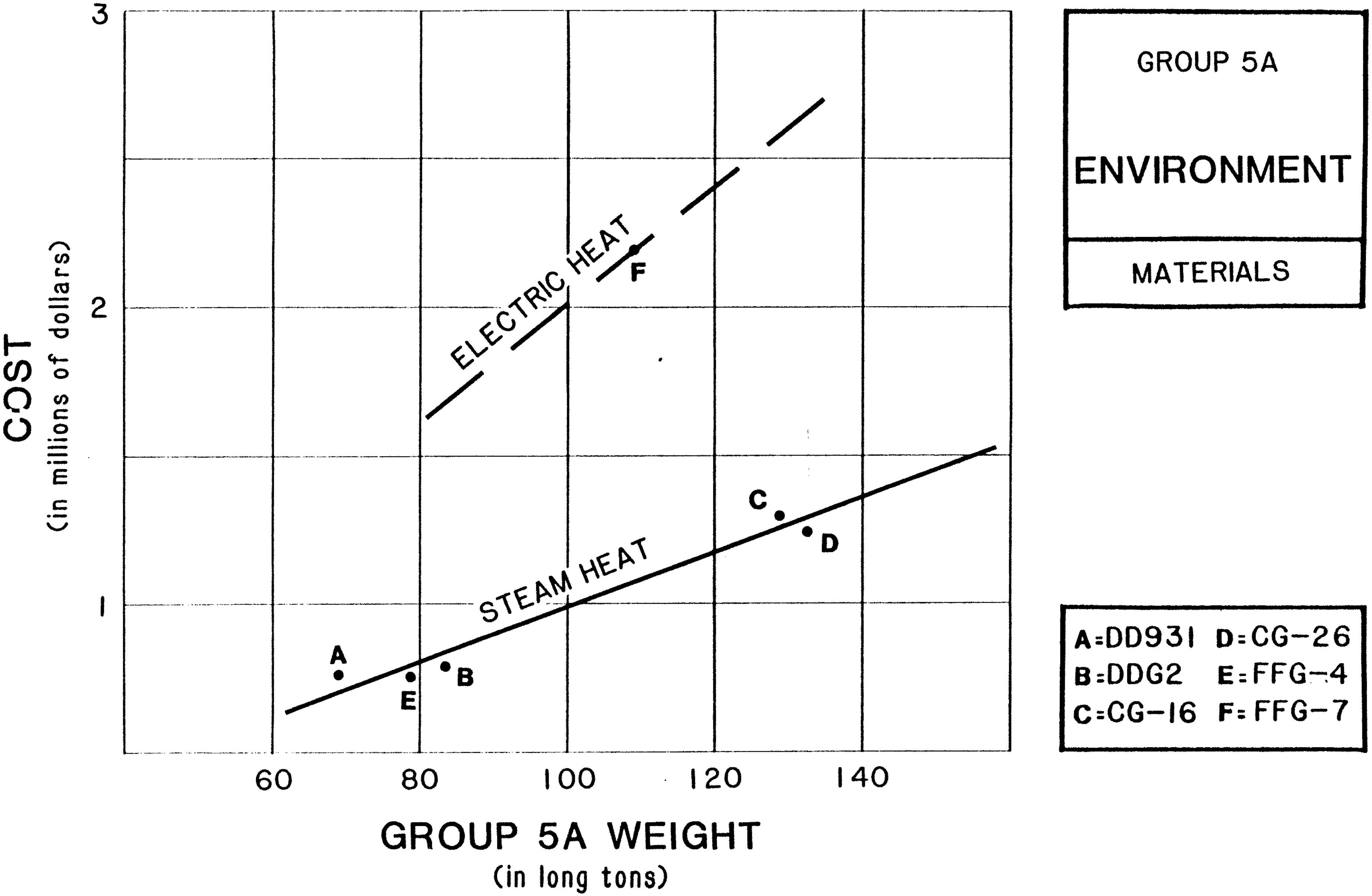

COST
(in millions of dollars)
3
2
1
60
80
100
120
140
GROUP 5A WEIGHT
(in long tons)
ELECTRIC HEAT
STEAM HEAT
A
B
C
D
E
F
GROUP 5A
ENVIRONMENT
MATERIALS
A=DD931
B=DDG2
C=CG-16
D=CG-26
E=FFG-4
F=FFG-7

Figure 3- 43

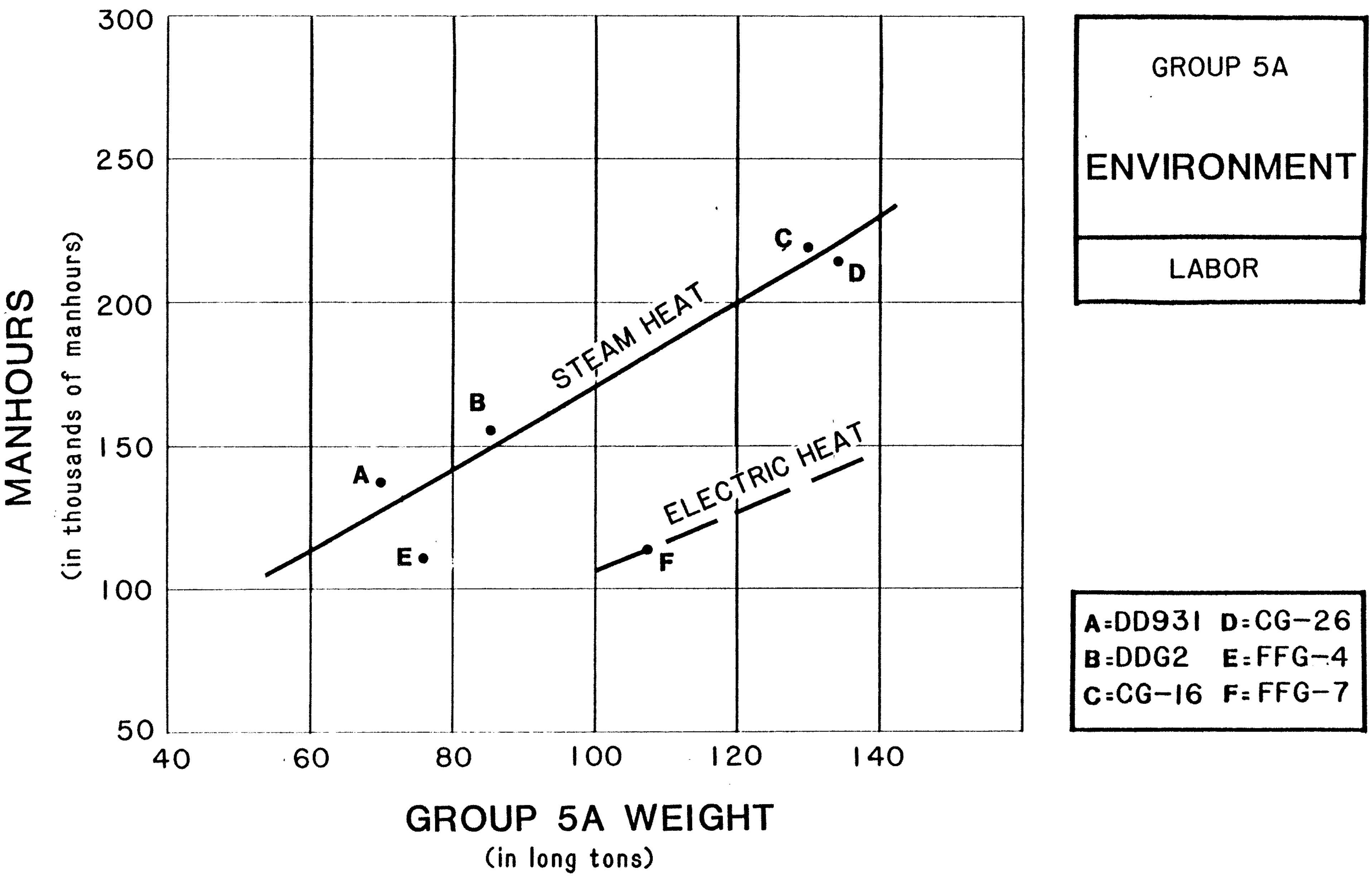

GROUP 5A
ENVIRONMENT
LABOR
MANHOURS
(in thousands of manhours)
300
250
200
150
100
50
40
60
80
100
120
140
GROUP 5A WEIGHT
(in long tons)
STEAM HEAT
ELECTRIC HEAT
A
B
C
D
E
F
A=DD931 D=CG-26
B=DDG2 E=FFG-4
C=CG-16 F=FFG-7

Figure 3- 44

system. The single missile (MK 13, Mod 4) has magazine flooding requirements which increases the required firemain capacity. A twin missile (DD 963) ship would have an even higher firemain capacity requirement.

CER: $ = 7,540 WT + 589,000
Variable: Group 5B Weight
Application: Steam, "Non-Missile"

CER: $ = 20,700 WT + 1,784,000
Variable: Group 5B Weight
Application: Gas Turbine, "Missile"

LABOR FACTOR: The considerations followed in developing the Group 5B material algorithms also apply to the labor curves. The non-missile algorithm is higher than the missile line due to the steam piping installation.

CER: MH = 1,150 WT - 32,000
Variable: Group 5B Weight
Application: Steam, "Non-Missile"

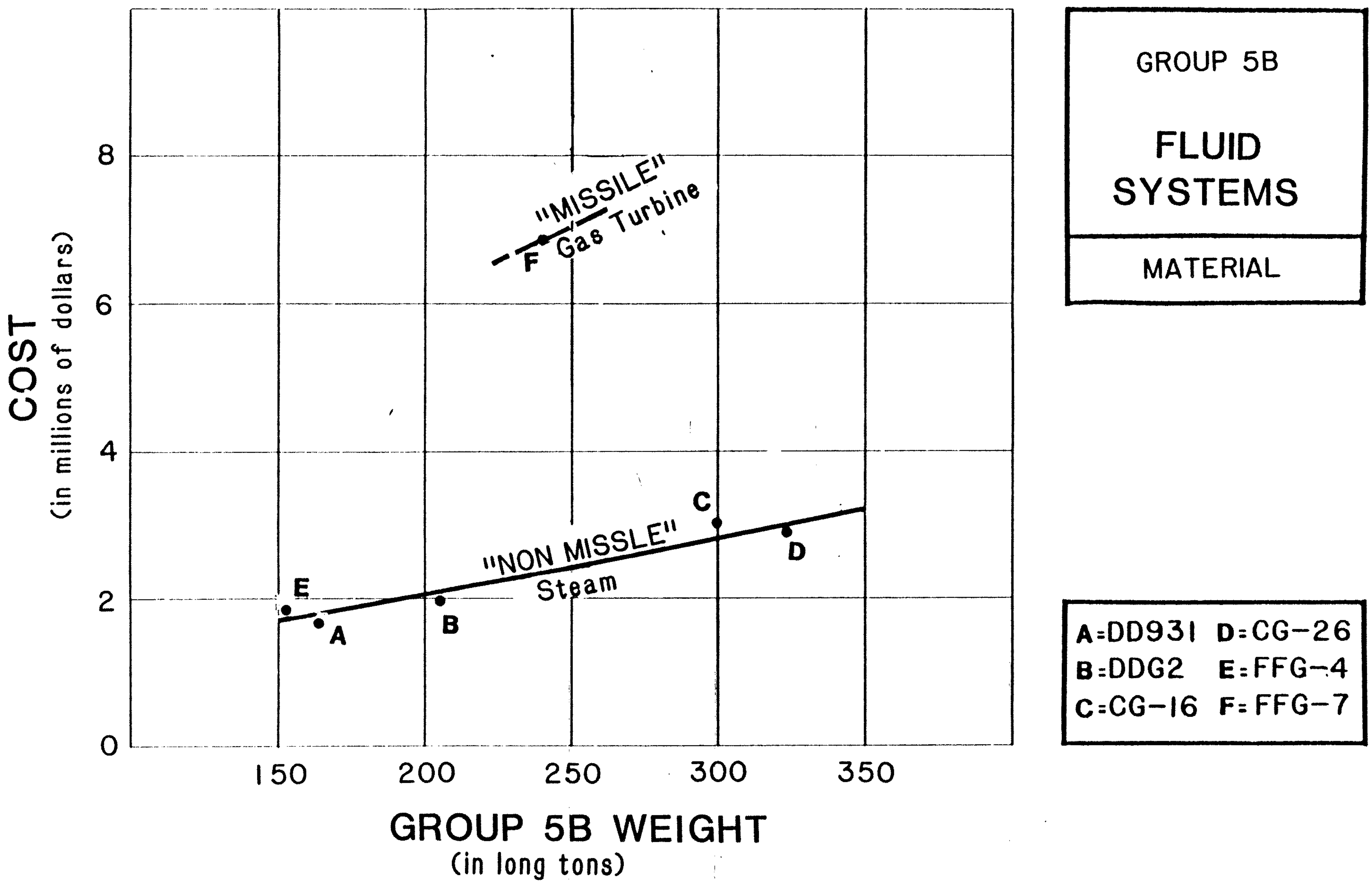
CER: MH = 796 WT - 19,300
Variable: Group 5B Weight
Application: Gas Turbine, "Missile"

See Figures 3-45 and 3-46 for graphs of data points.

Group 5C - Maneuvering

This group includes the steering system and rudders.

MATERIAL FACTOR: Group 5C material costs can be estimated as a function of the length x draft (L x H/100).s



COST
(in millions of dollars)
0
2
4
6
8
150
200
250
300
350
GROUP 5B WEIGHT
(in long tons)
"MISSILE"
Gas Turbine
F
"NON MISSLE"
Steam
A
B
C
D
E
GROUP 5B
FLUID SYSTEMS
MATERIAL
A=DD931 D=CG-26
B=DDG2 E=FFG-4
C=CG-16 F=FFG-7


Figure 3-45

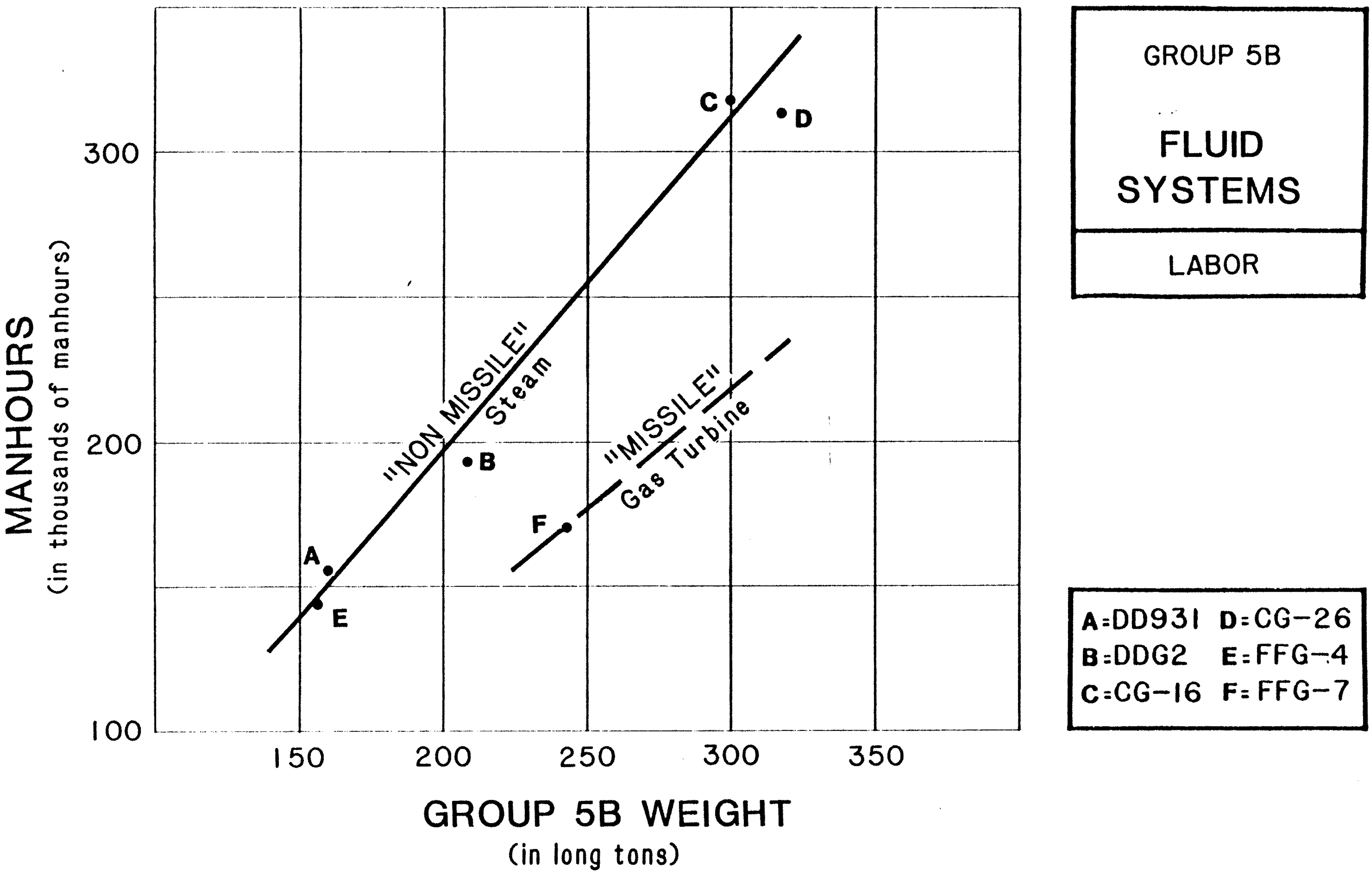

GROUP 5B
FLUID SYSTEMS
LABOR
MANHOURS
(in thousands of manhours)
300
200
100
150
200
250
300
350
GROUP 5B WEIGHT
(in long tons)
"NON MISSILE" Steam
"MISSILE" Gas Turbine
A
B
C
D
E
F
A=DD931 D=CG-26
B=DDG2 E=FFG-4
C=CG-16 F=FFG-7

Figure 3- 46

FFG-7 could form the basis of a second algorithm to include vessels with NIXIE (torpedo decoys). This results in a larger steering gear room (SWBS 561) than necessary for a vessel of her size. CG-26 was excluded from the algorithms because of the cost effect of a multiple buy. Also, it is the same steering system as CG-16, just stretched.

CER: 3,730 (L x H/100) + 56,000
Variable: Length x Draft
Application: All (Without Nixie)

LABOR FACTOR: Man-hours are also a function of the length x draft (L x H/100) for Group 5C with CG-26 and DD-931 as outliers. CG-26 was discussed earlier. DD-931 has high man-hours for this group somewhat because of error in classification of group weights and higher weight and cost associated with it having a twin rudder system.

CER: MH = 174.8 (L x H/100) - 3,000
Variation: Length x Draft
Application: All

See Figures 3-47 and 3-48 for graphs of data points.

Group 5D Handling

This group includes mooring systems, aircraft handling systems, elevators, stabilizers and other miscellaneous auxiliary machinery.

There is no one algorithm for group 5D material or labor costs. This group is characteristically vendor supplied, highly specialized, and individually tailored for each ship.

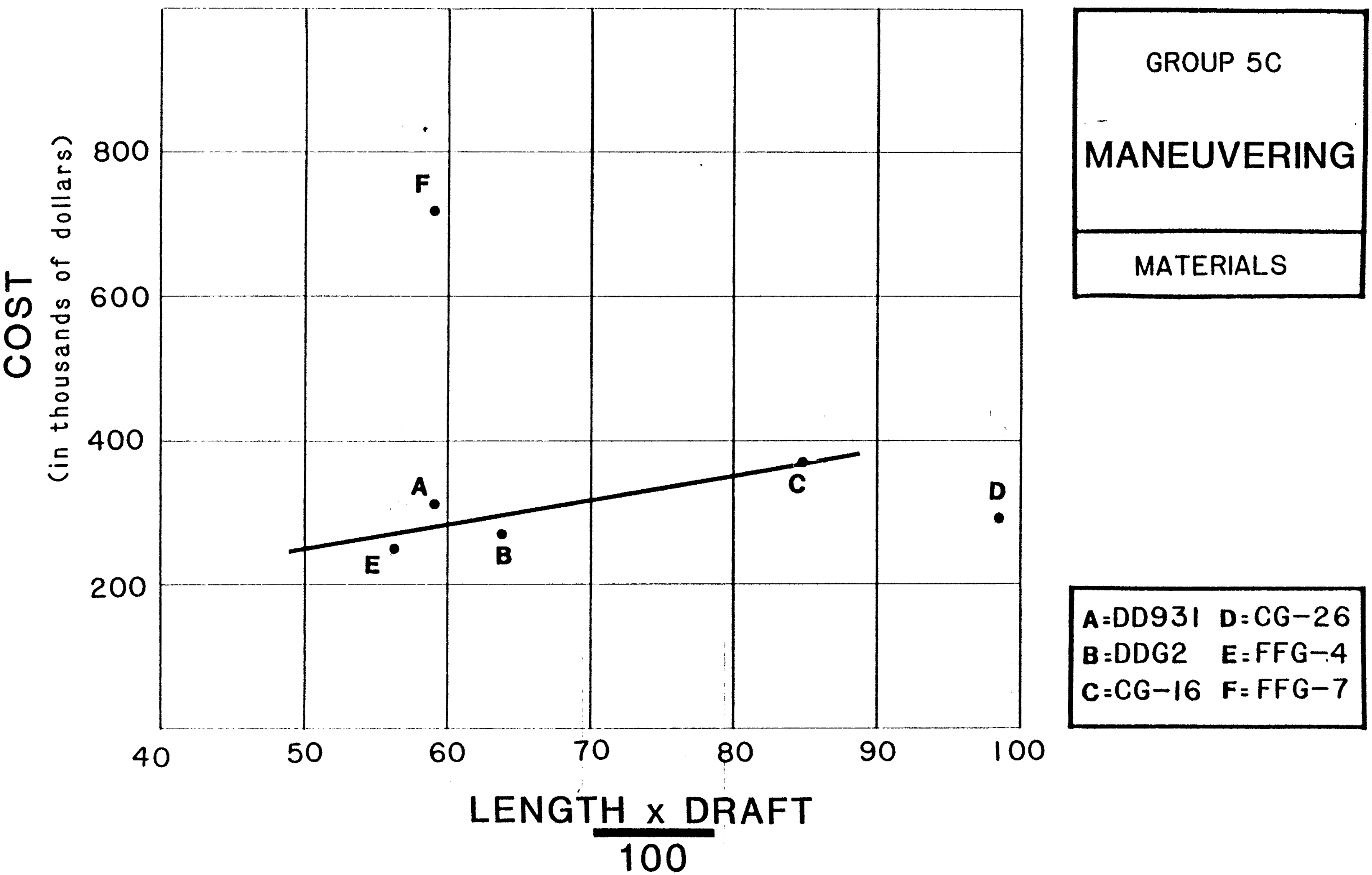

GROUP 5C
MANEUVERING
MATERIALS
COST
(in thousands of dollars)
800
600
400
200
40
50
60
70
80
90
100
LENGTH x DRAFT
100
F
A
B
C
D
E
A=DD931 D=CG-26
B=DDG2 E=FFG-4
C=CG-16 F=FFG-7

Figure 3-47

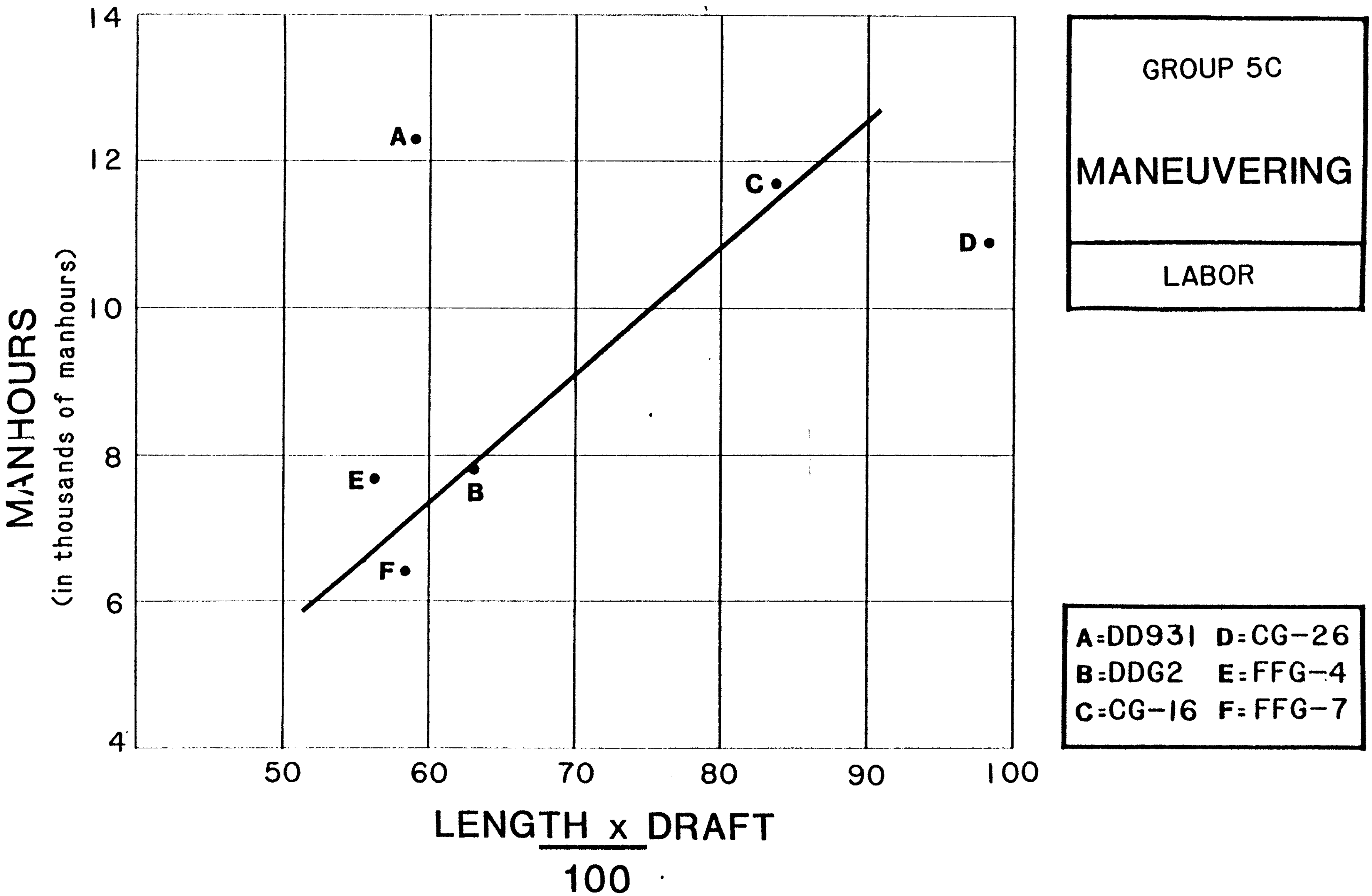

GROUP 5C
MANEUVERING
LABOR
MANHOURS
(in thousands of manhours)
LENGTH x DRAFT / 100
14
12
10
8
6
4
50
60
70
80
90
100
A
B
C
D
E
F
A=DD931 D=CG-26
B=DDG2 E=FFG-4
C=CG-16 F=FFG-7

Figure 3-48

MATERIAL FACTOR: Items such as elevators and windlasses can vary greatly in cost and weight between different vendors. A major factor of this vendor material cost is the Navy's software requirements for the vendors on top of the shipyard software requirements (Groups 8 and 9). The cost of this software is included in the cost of handling equipment far above the normal inflationary increase. This can be seen in the relatively high costs of the FFG-7 and FFG-4 as compared to other ships with the same Group 5D weight. While no algorithm is supplied here, factors from 9,000 to 12,000 dollars per ton would be within an acceptable range for current technology ship handling items.

CER: $ = 9,000 WT -to- $ = 12,000. WT
Variable: Group 5D Weight
Application: Current Technology

LABOR FACTOR: As discussed above, no trend line has been supplied because of the variable nature of this cost group. An acceptable range for the labor factors is from 200 to 300 man-hours per ton for current technology items.

CER: MH = 200 WT -to- MH = 300 WT
Variable: Group 5D Weight
Application: Current Technology

See Figures 3-49 and 3-50 for graphs of data points.

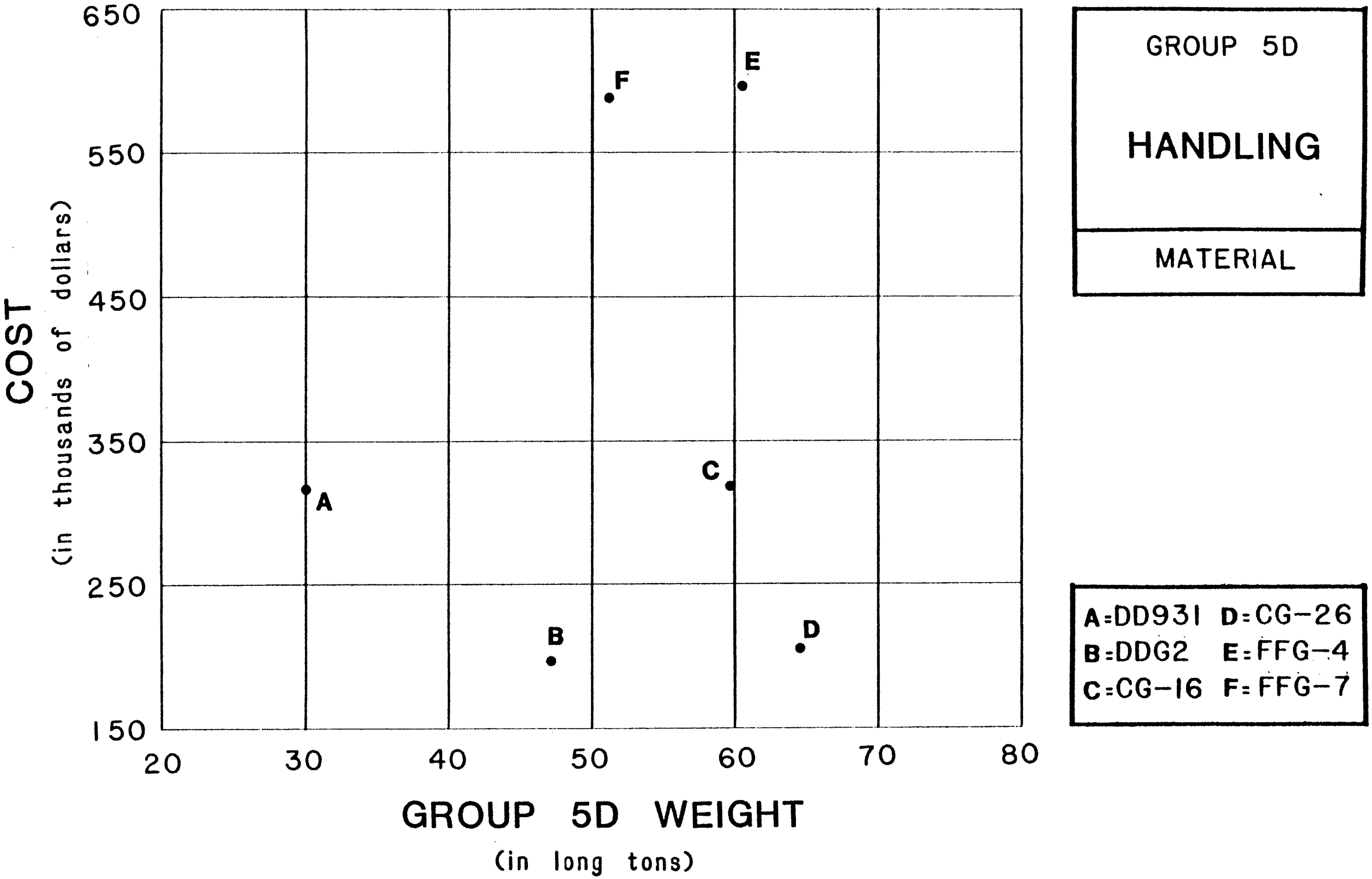

GROUP 5D
HANDLING
MATERIAL
COST
(in thousands of dollars)
650
550
450
350
250
150
20
30
40
50
60
70
80
GROUP 5D WEIGHT
(in long tons)
A
B
C
D
E
F
A=DD931
B=DDG2
C=CG-16
D=CG-26
E=FFG-4
F=FFG-7

Figure 3-49

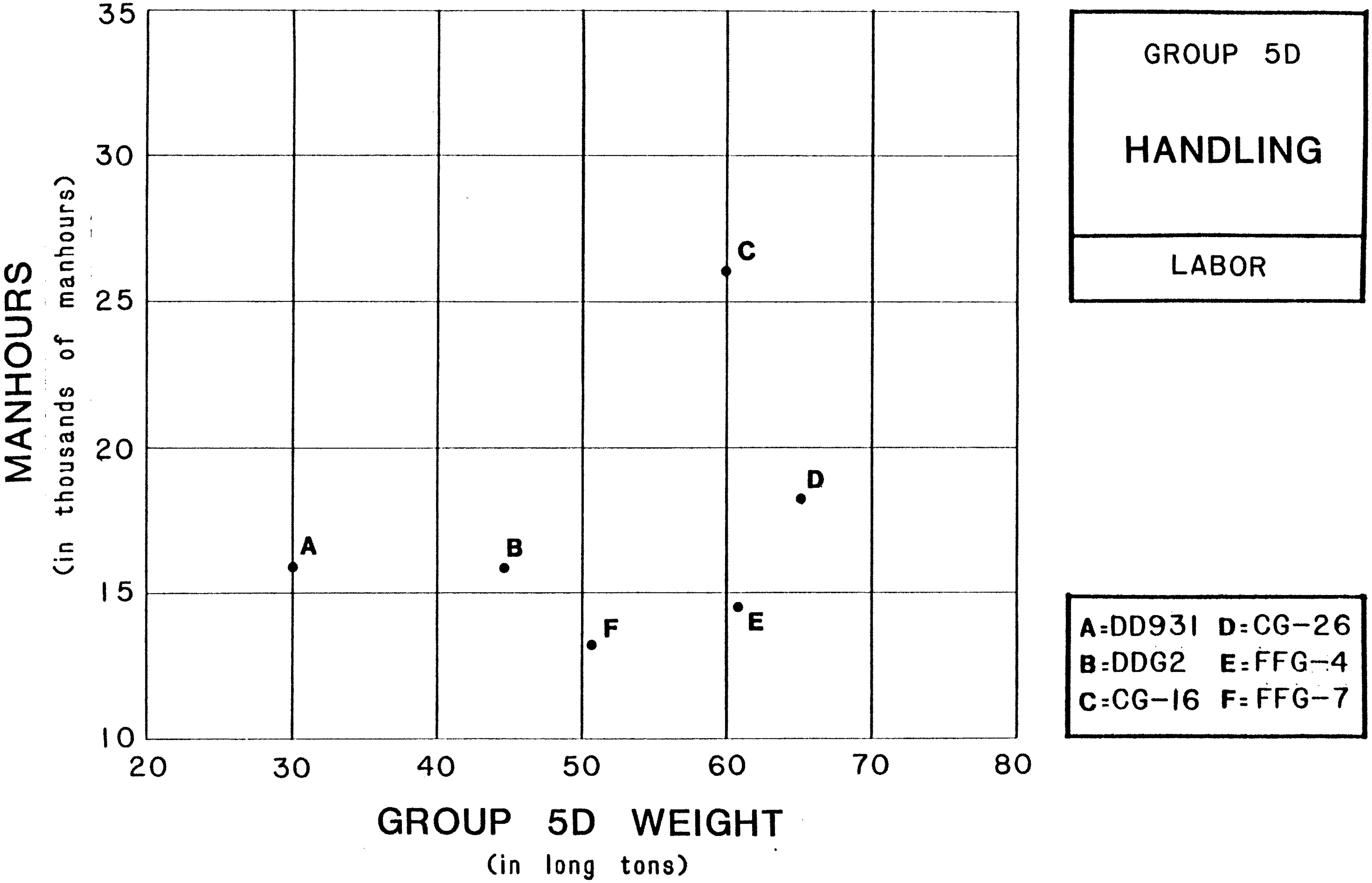

GROUP 5D
HANDLING
LABOR
MANHOURS
(in thousands of manhours)
35
30
25
20
15
10
20
30
40
50
60
70
80
A
B
C
D
E
F
A=DD931 D=CG-26
B=DDG2 E=FFG-4
C=CG-16 F=FFG-7
GROUP 5D WEIGHT
(in long tons)

Figure 3-50

### 3.4.6 Group 6 - Outfit

6A Hull Fittings
6B Nonstructural Subdivisions
6C Preservation
6D Facilities
6E Habitability

MATERIAL FACTOR: For the two-digit Group 6 material costs, several different parameters emerged as the most explanatory variable depending on the type of outfit being costed. For example, Group 6B graphs best as a function of the group weight while Group 6D reflects the impact of the ships complement. Despite these differences, for the aggregate Group 6, the independent variables of either weight or length x beam (L x B) produce the best fit. For both graphs, there are two algorithms reflecting the change in habitability standards, pre-1965 and post-1965 habitability standards. (At this one-digit level, the pre-1956 standards in effect for the DD-931 and DDG-2 do not seem to be a factor.)

CER: $\$ = 84.6\ (LxB) + 46,000$
Variable: Length x Beam
Application: Pre-1965 Habitability

CER: $\$ = 151.3\ (LxB) + 302,000$
Variable: Length x Beam
Application: Post-1965 Habitability

OR

CER: $\$ = 4,850\ WT + 462,000$
Variable: Group 6 Weight
Application: Pre-1965 Habitability

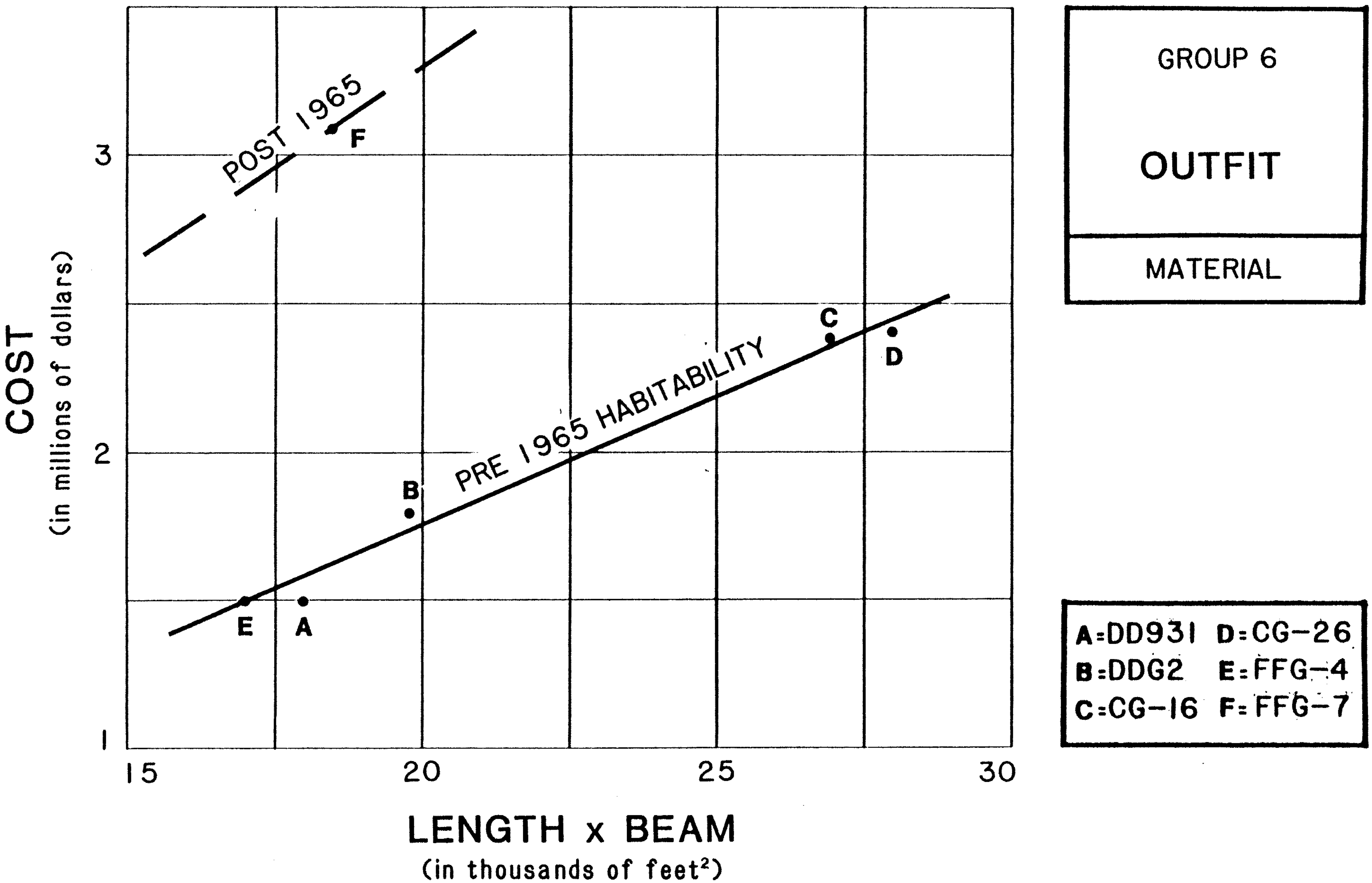
CER: $ = 7,380 WT + 777,000
Variable: Group 6 Weight
Application: Post-1965 Habitability

LABOR FACTOR: As with the Group 6 material costs the Group 6 two-digit level labor functions used different parameters. For the total Group 6 man-hours, the vessel's length x beam (L x B) can be used to estimate man-hours. Each utilizes two algorithms, one for old habitability standards (pre-1965) and one for the newer habitability standards as outlined in the 1979 habitability instructions. (FFG 7 costs reflect these higher standards even though it was delivered in 1975.) For future vessels the standards for space requirements and other habitability items may not be as high as FFG-7. As modularization of components (prefabricated units) becomes more standard, labor costs for Group 6 should decrease.

CER: MH = 22.2 (L x B) - 88,000
Variable: Length x Beam
Application: Post-1965 Habitability

CER: MH = 20.7 (L x B) - 88,000
Variable: Length x Beam
Application: Pre-1965 Habitability

See Figures 3-51 through 3-53 for graphs of data points.



POST 1965
PRE 1965 HABITABILITY
COST
(in millions of dollars)
3
2
1
15
20
25
30
LENGTH x BEAM
(in thousands of feet²)
A
B
C
D
E
F
GROUP 6
OUTFIT
MATERIAL
A=DD931 D=CG-26
B=DDG2 E=FFG-4
C=CG-16 F=FFG-7


Figure 3-51

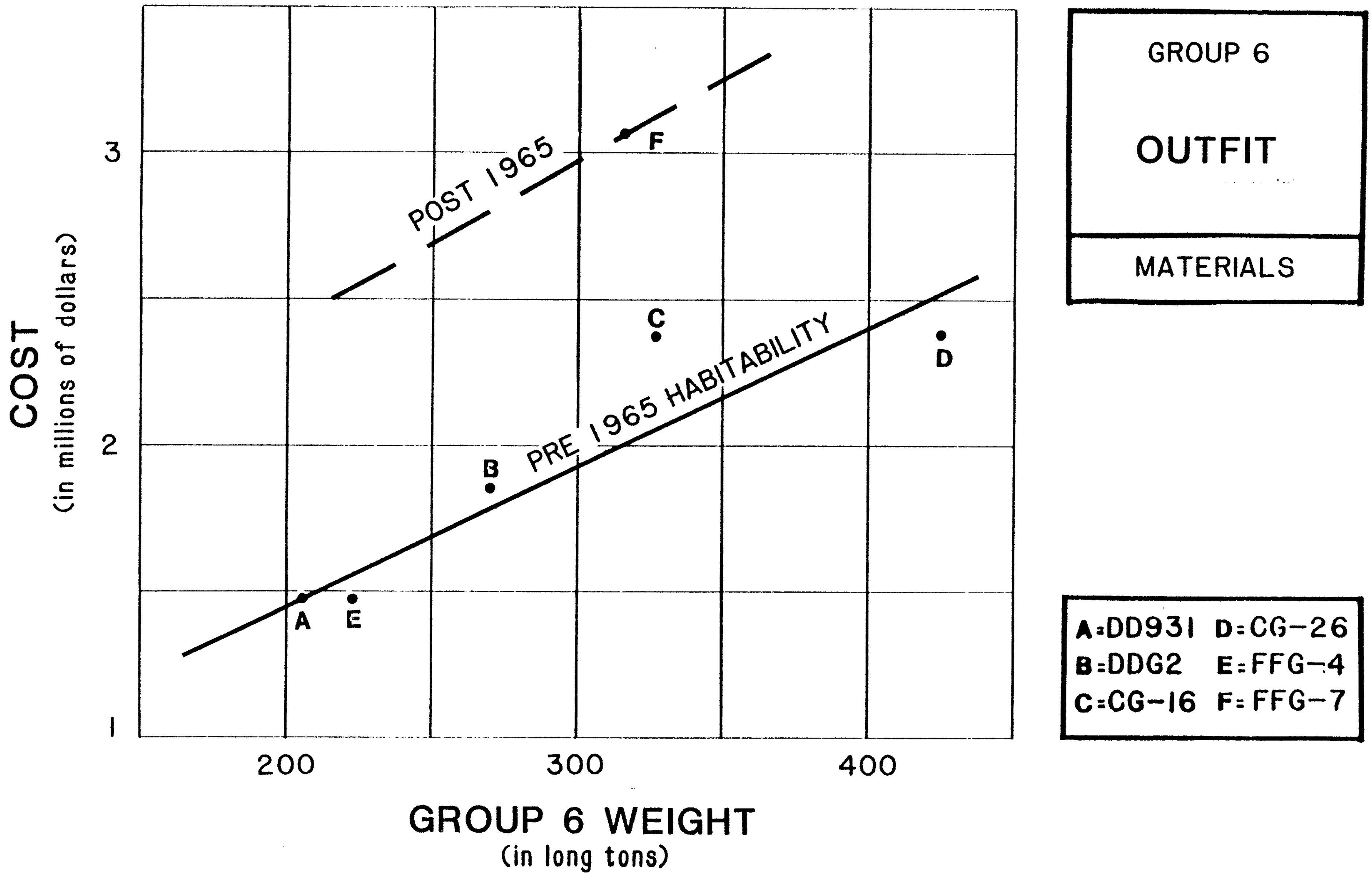

GROUP 6
OUTFIT
MATERIALS
POST 1965
PRE 1965 HABITABILITY
A
B
C
D
E
F
COST
(in millions of dollars)
1
2
3
200
300
400
GROUP 6 WEIGHT
(in long tons)
A=DD931 D=CG-26
B=DDG2 E=FFG-4
C=CG-16 F=FFG-7

Figure 3-52

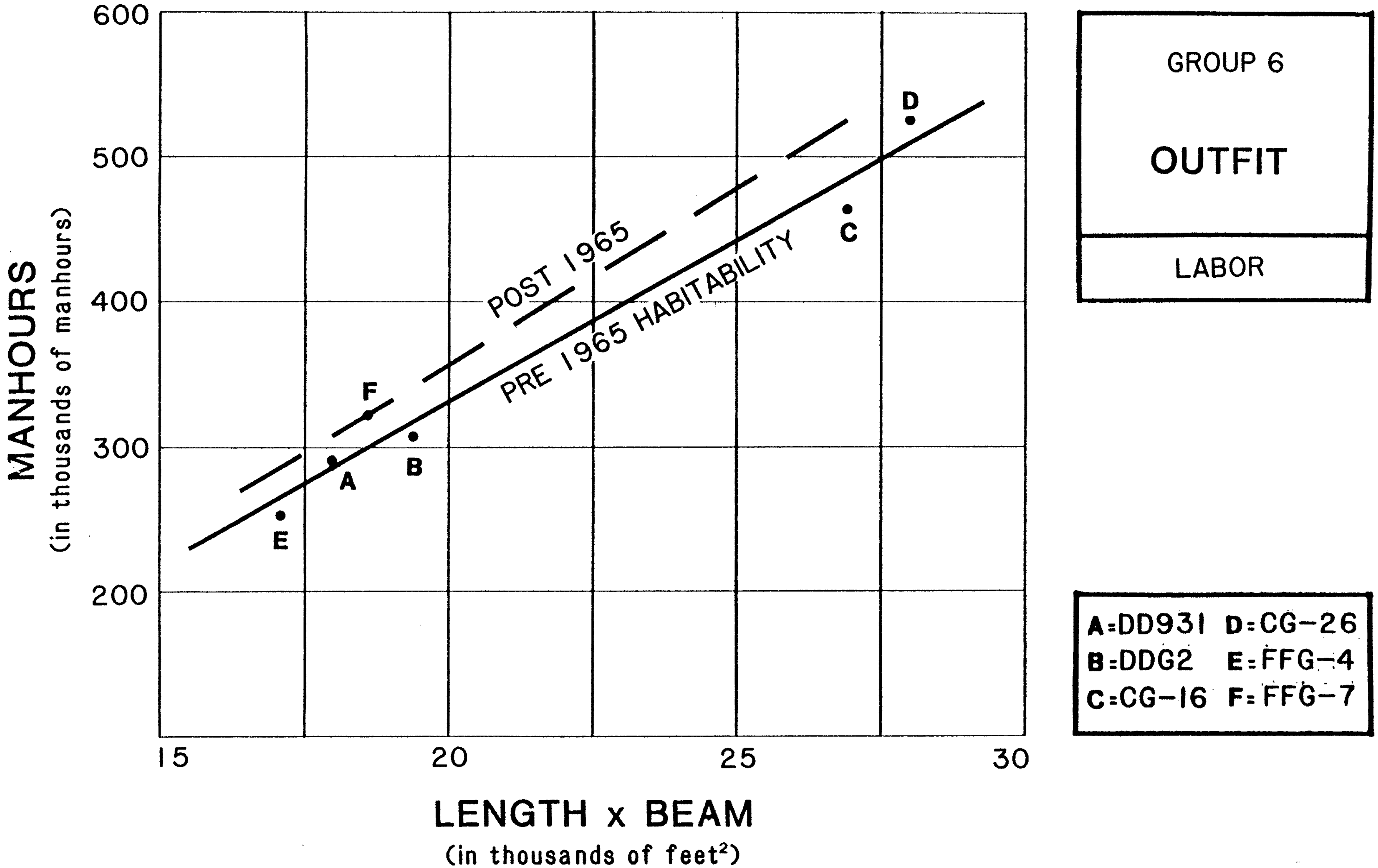

GROUP 6
OUTFIT
LABOR
A=DD931 D=CG-26
B=DDG2 E=FFG-4
C=CG-16 F=FFG-7
MANHOURS
(in thousands of manhours)
LENGTH x BEAM
(in thousands of feet²)
POST 1965
PRE 1965 HABITABILITY
600
500
400
300
200
15
20
25
30
A
B
C
D
E
F

Figure 3- 53

Group 6A Hull Fittings

This group includes hull fittings, boats, liferafts and associated gear.

MATERIAL FACTOR: Group 6A material costs as a function of Length x Beam fall into two algorithms, one for current technology and one for earlier technology. Most of the equipment is standardized in type and weight for destroyers.

CER: $ = 11 (LxB) + 42,000
Variable: Length x Beam
Application: Early Technology

CER: $ = 18 (LxB) + 102,000
Variable: Length x Beam
Application: Current Technology

LABOR FACTOR: A single algorithm for 6A labor is sufficient to estimate the man-hours based on the weight of this group.

CER: MH = 718 WT - 1,300
Variable: Group 6A Weight
Application: All

See Figures 3-54 and 3-55 for graphs of data points.

Group 6B Nonstructural Subdivisions

This group includes ladders, nonstructural bulkheads and doors, sheathing, etc.

MATERIAL FACTOR: The two algorithms for Group 6B material costs cover pre-1965 habitability standards and

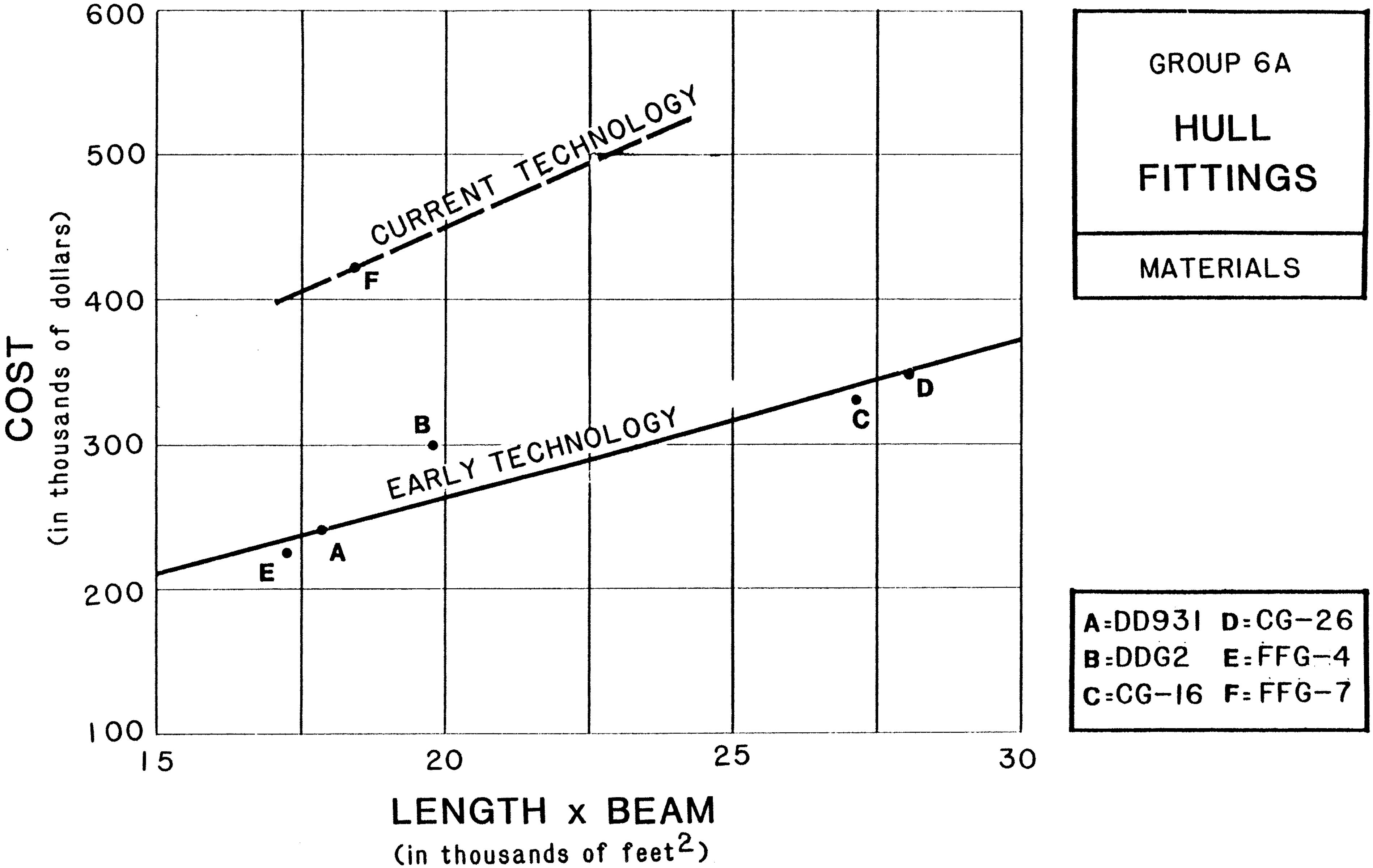

GROUP 6A
HULL FITTINGS
MATERIALS
COST
(in thousands of dollars)
600
500
400
300
200
100
15
20
25
30
LENGTH x BEAM
(in thousands of feet2)
CURRENT TECHNOLOGY
EARLY TECHNOLOGY
A
B
C
D
E
F
A=DD931
B=DDG2
C=CG-16
D=CG-26
E=FFG-4
F=FFG-7

Figure 3-54

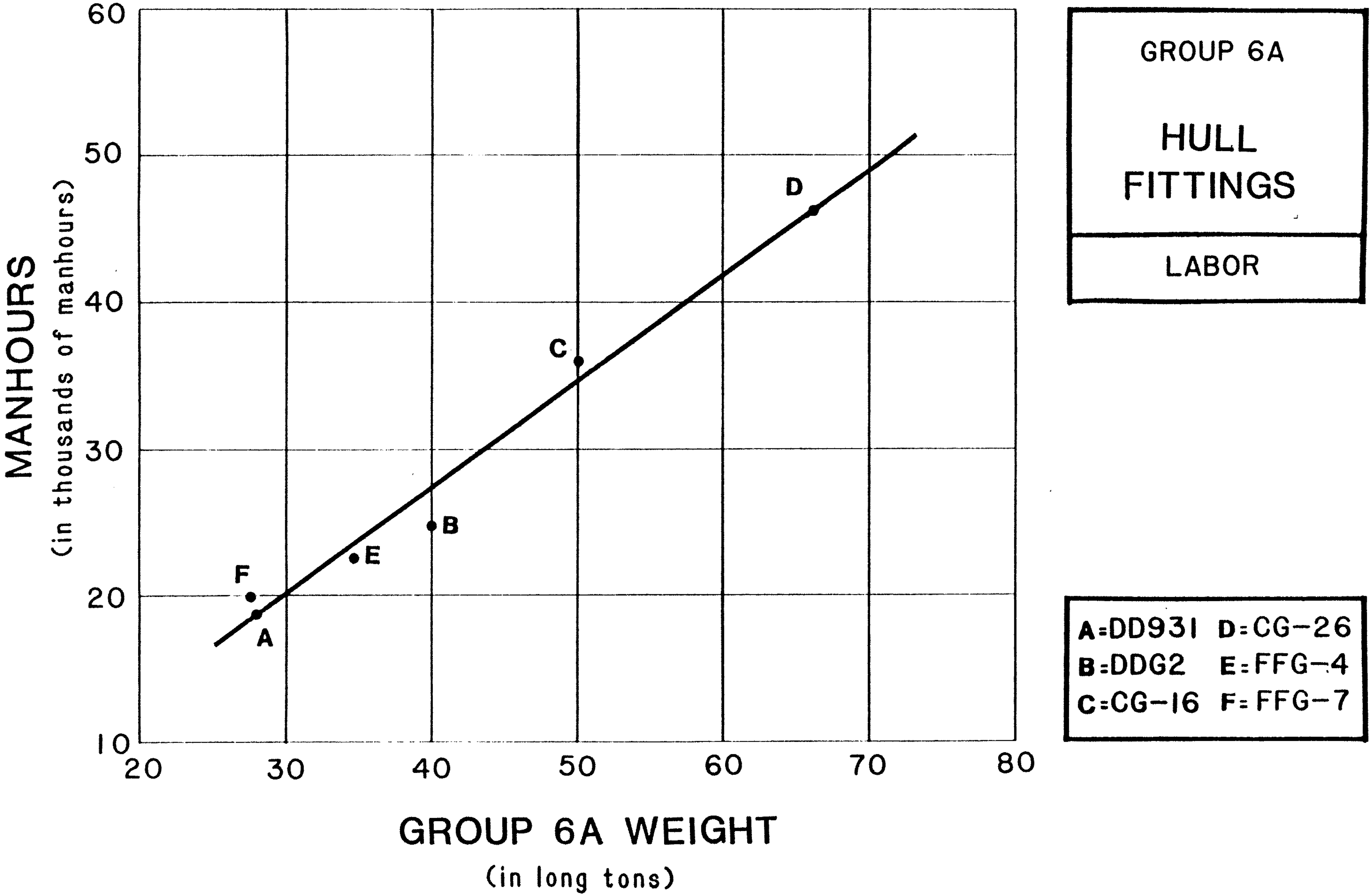

GROUP 6A
HULL FITTINGS
LABOR
MANHOURS
(in thousands of manhours)
GROUP 6A WEIGHT
(in long tons)
A=DD931 D=CG-26
B=DDG2 E=FFG-4
C=CG-16 F=FFG-7
60
50
40
30
20
10
20
30
40
50
60
70
80
A
B
C
D
E
F

Figure 3- 55

post-1965 habitability standards. Several parameters were investigated to determine the best fit, which was material costs as a function of the group weight. Cost versus length x depth (L x D) also produced a satisfactory algorithm. For the pre-1965 standard algorithm, there are no significant variations. The post-1965 standards are reflected in the FFG-7 with increased compartmentation and sheathing in crew spaces. Also reflected is the trend back toward steel gratings as opposed to aluminum, which had a very poor service life and were unsatisfactory for machinery space use because of fire. (Future ships may not have as much compartmentation as the FFG-7 class.)

CER: $ = 8.42 (LxD) + 104,000
Variable: Length x Depth
Application: Pre-1965 Habitability

CER: $ = 24.2 (LxD) + 272,000
Variable: Length x Depth
Application: Post-1965 Habitability

OR

CER: $ = 2,260 WT + 119,000
Variable: Group 6B Weight
Application: Pre-1965 Habitability

CER: $ = 4,830 WT + 266,000
Variable: Group 6B Weight
Application: Post-1965 Habitability

LABOR FACTOR: For the Group 6B man-hours, several parameters were tried with the most satisfactory algorithm being man-hours as a function of the ship's weight. For the pre-1965 habitability standard vessels, DD-931 is an outlier, which may be due to steel gratings in SWBS Element 622 where the others have aluminum gratings. (DDG-2 has steel gratings also but is not an outlier.) The post-1965 algorithm reflects increased standards for compartmentation, sheathing and the like.

CER: MH = 1,210 WT + 2,600
Variable: Group 6B Weight
Application: All

See Figures 3-56 through 3-58 for graphs of data points.

Group 6C Preservation

This group includes painting, deck covering, and hull insulation.

MATERIAL FACTOR: The best independent variable to estimate Group 6C costs is the variable length x beam (L x B). Painting (SWBS Element 631) is usually a function of the Group 1 total weight, while deck covering is a function of the length x beam (L x B) and the habitability standards under which the ship was constructed. SWBS Element 633, hull insulation, is also a function of the habitability standard; therefore, it is logical that material costs as a function of L x B fall into two algorithms -- earlier versus current habitability standards. The current standards include the use of better thermal and acoustic insulation (higher HVAC

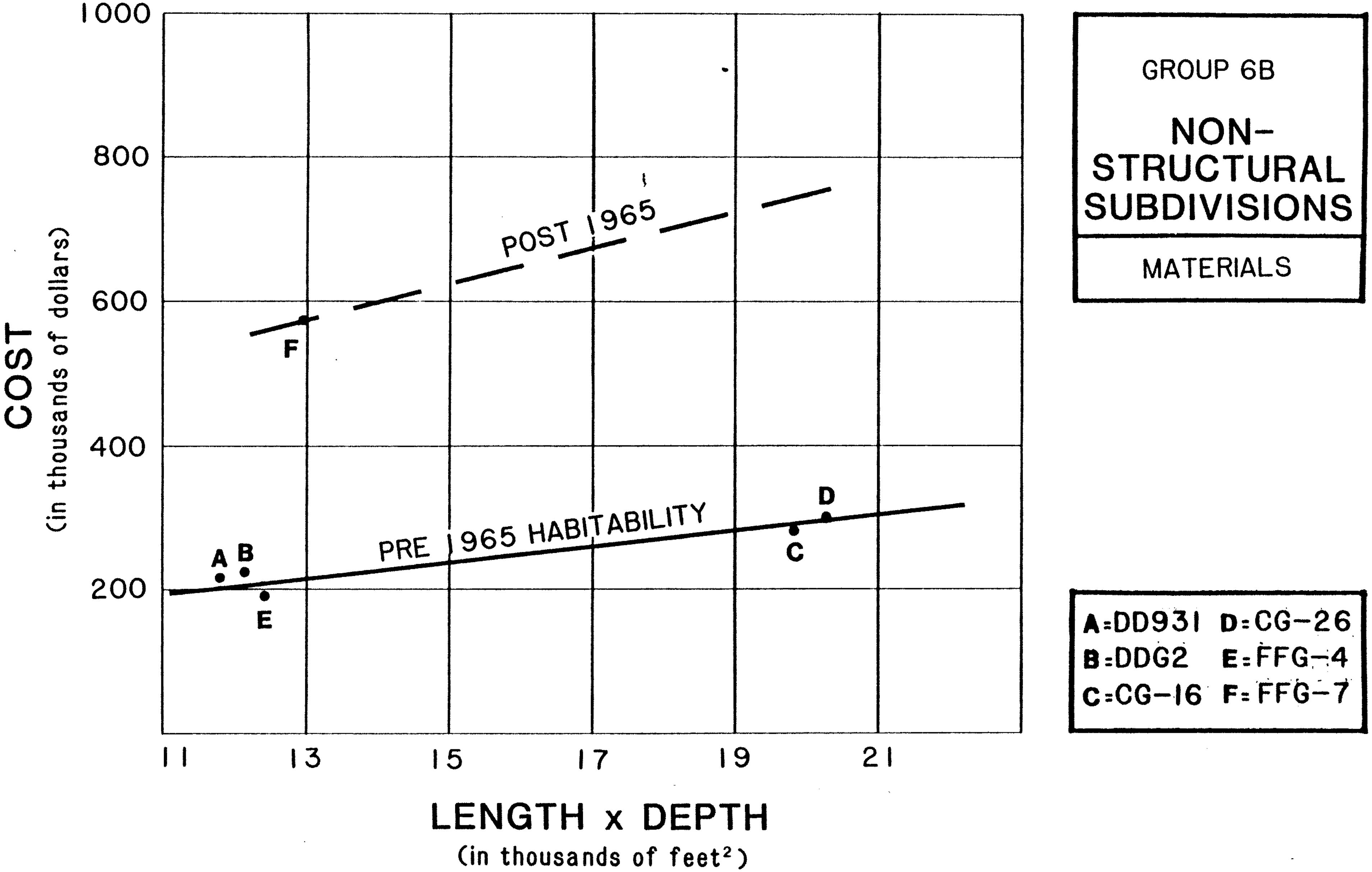
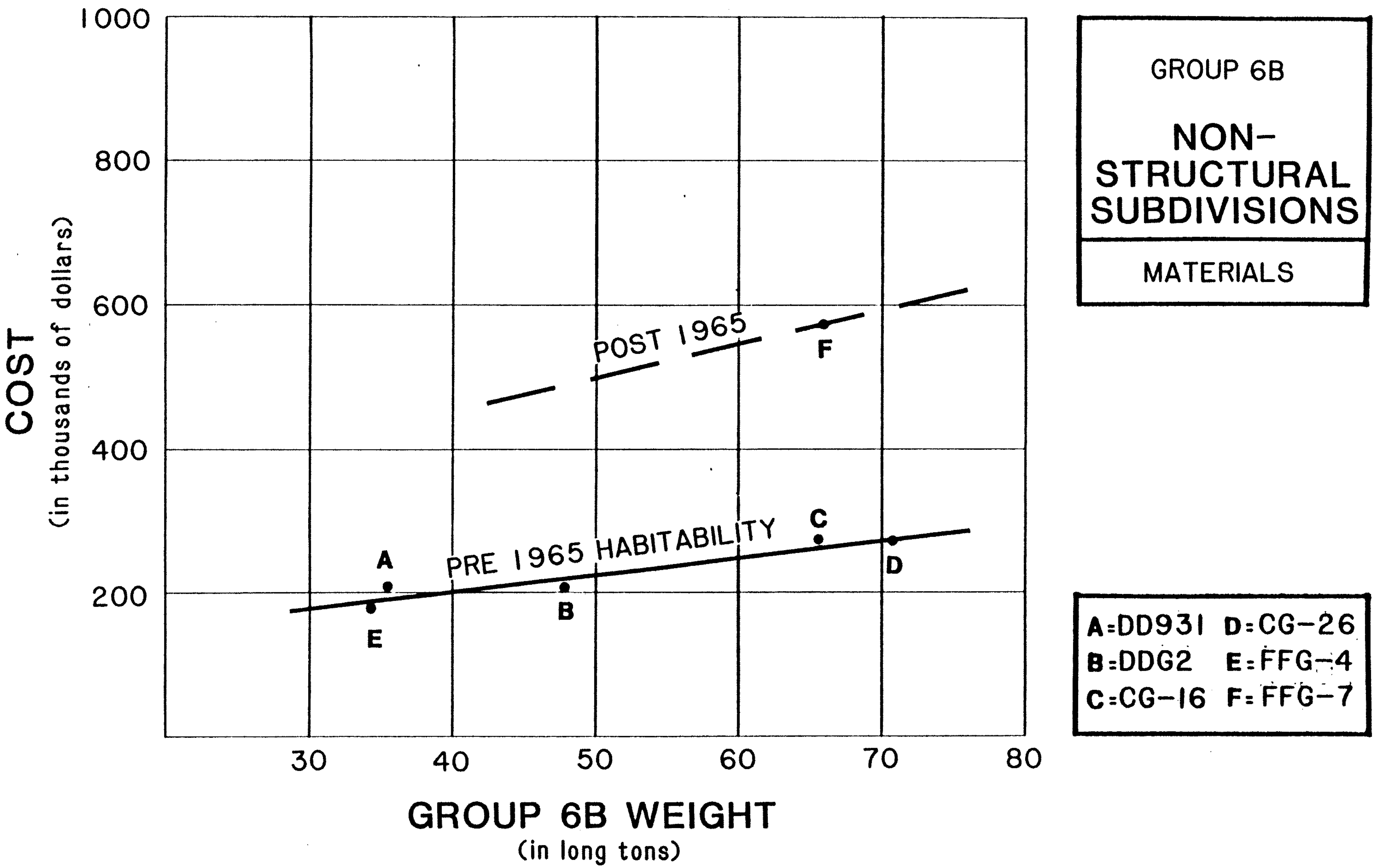

1000
800
600
400
200
COST
(in thousands of dollars)
11
13
15
17
19
21
LENGTH x DEPTH
(in thousands of feet²)
POST 1965
PRE 1965 HABITABILITY
A
B
C
D
E
F
GROUP 6B
NON-STRUCTURAL SUBDIVISIONS
MATERIALS
A=DD931 D=CG-26
B=DDG2 E=FFG-4
C=CG-16 F=FFG-7

Figure 3-56



GROUP 6B
NON-STRUCTURAL SUBDIVISIONS
MATERIALS
COST (in thousands of dollars)
1000
800
600
400
200
30
40
50
60
70
80
GROUP 6B WEIGHT (in long tons)
POST 1965
PRE 1965 HABITABILITY
A
B
C
D
E
F
A=DD931 D=CG-26
B=DDG2 E=FFG-4
C=CG-16 F=FFG-7


Figure 3-57

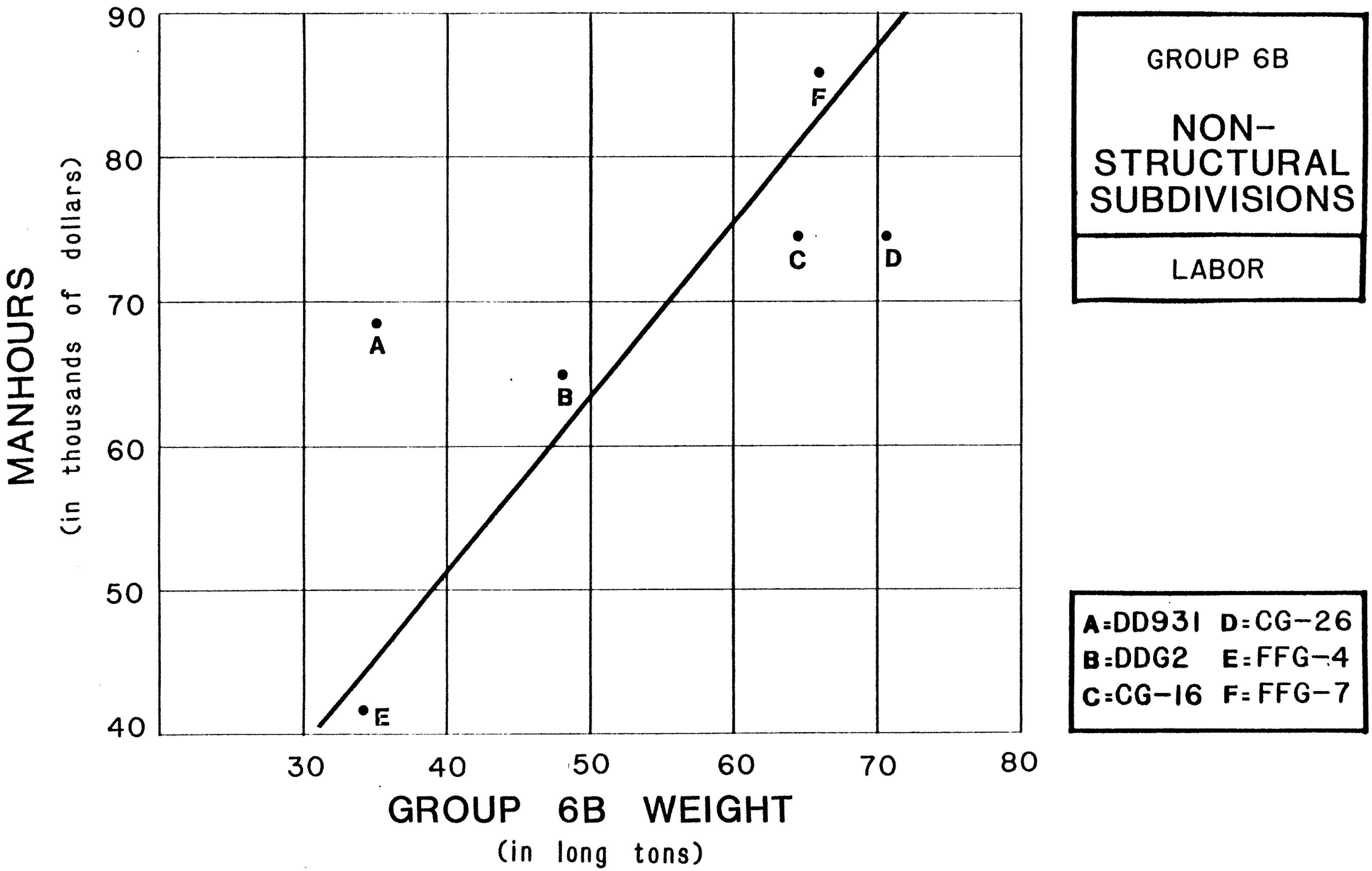

GROUP 6B
NON-STRUCTURAL SUBDIVISIONS
LABOR
MANHOURS
(in thousands of dollars)
90
80
70
60
50
40
30
40
50
60
70
80
GROUP 6B WEIGHT
(in long tons)
A
B
C
D
E
F
A=DD931 D=CG-26
B=DDG2 E=FFG-4
C=CG-16 F=FFG-7

Figure 3- 58

standards) and lighter weight, more expensive carpeting and the accommodations instead of tile. The reason for FFG-4 being lower in material costs is a lower figure for sonar sound damping insulation.

CER: $ = 38.9 (LxB) - 297,000
Variable: Length x Beam
Application: Early Technology

CER: $ = 53.5 (LxB) - 398,000
Variable: Length x Beam
Application: Current Technology

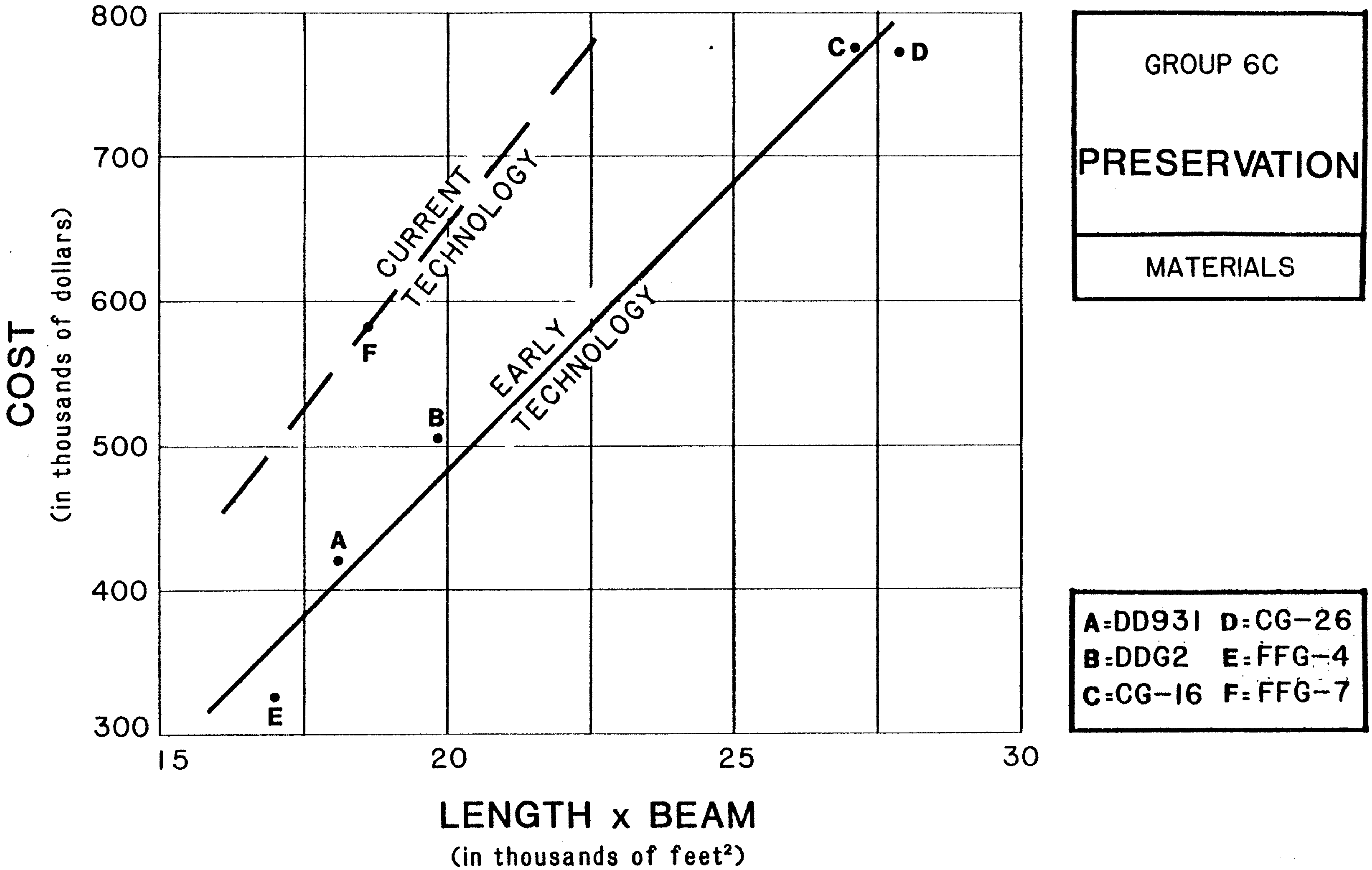
LABOR FACTOR: Using the independent variable of length x beam yields an algorithm with a high coefficient of determination for the same reasons as listed above. The only difference is that habitability standards only seem to affect the materials involved, not the associated man-hours, so that one algorithm is satisfactory for Group 6C labor. This higher labor rate for CG-26 reflects the installation of full sonar sound damping.

CER: MH = 14.4 (LxB) - 128,600
Variable: Length x Beam
Application: All

See Figures 3-59 and 3-60 for graphs of data points.

Group 6D Facilities

This group includes storerooms and equipment for utility spaces and workshops. A utility space is defined as any



GROUP 6C
PRESERVATION
MATERIALS
COST
(in thousands of dollars)
800
700
600
500
400
300
15
20
25
30
LENGTH x BEAM
(in thousands of feet²)
CURRENT TECHNOLOGY
EARLY TECHNOLOGY
A
B
C
D
E
F
A=DD931 D=CG-26
B=DDG2 E=FFG-4
C=CG-16 F=FFG-7


Figure 3-59

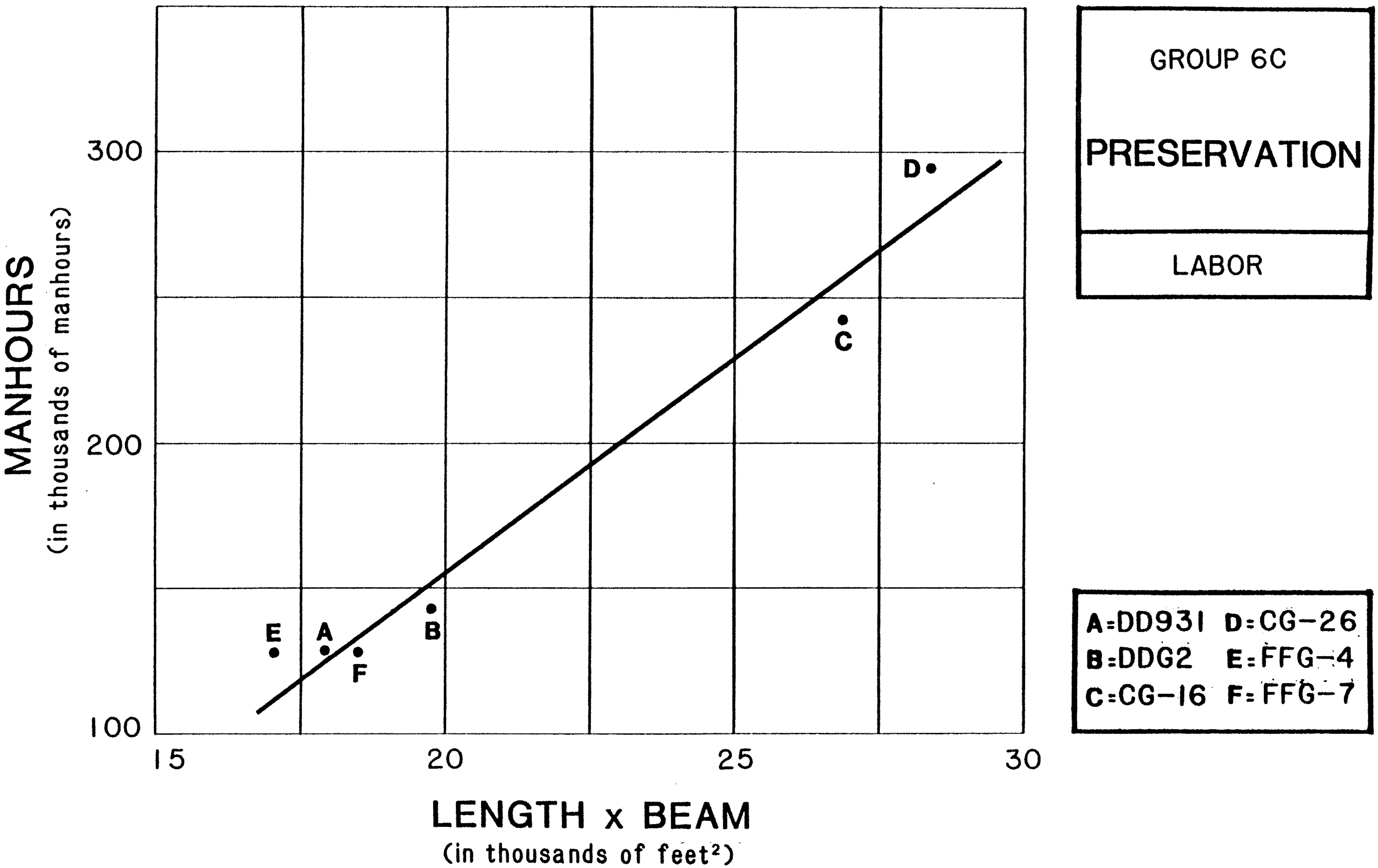

GROUP 6C
PRESERVATION
LABOR
MANHOURS
(in thousands of manhours)
300
200
100
15
20
25
30
LENGTH x BEAM
(in thousands of feet²)
A
B
C
D
E
F
A=DD931 D=CG-26
B=DDG2 E=FFG-4
C=CG-16 F=FFG-7

Figure 3- 60

space that is required aboard the ship to provide for the basic necessities of the crew.

MATERIAL FACTOR: The algorithms for Group 6D material costs as a function of complement cover two habitability standards -- 1956 to 1965 standards and post-1965 to the latest habitability standards. The pre-1956 standards (DD-931) are not readily apparent in other areas where habitability concerns are a factor, because in those areas, the influence on cost was not significant. The new standards include the heavy VIDMAR storage cabinets, improved facilities for the crew, and increased locker and stowage space per man.

CER: $ = 238 COMP + 159,000
Variable: Complement
Application: Pre-1965 Habitability

CER: $ = 489 COMP + 328,000
Variable: Complement
Application: Post-1965 Habitability

LABOR FACTOR: For Group 6D man-hours, the independent variable of weight is sufficient for a good estimate. The algorithm for the new habitability standards applies to destroyers with such special outfit as the heavier VIDMAR cabinets. (VIDMAR cabinets for a frigate type ship weigh over 20 tons, but are much easier to install.)

CER: MH = 553 WT + 5,300
Variable: Group 6D Weight
Application: Post-1965 Habitability

CER: MH = 876 WT + 9,700
Variable: Group 6D Weight
Application: Pre-1965 Habitability

See Figures 3-61 and 3-62 for graphs of data points.

Group 6E Habitability

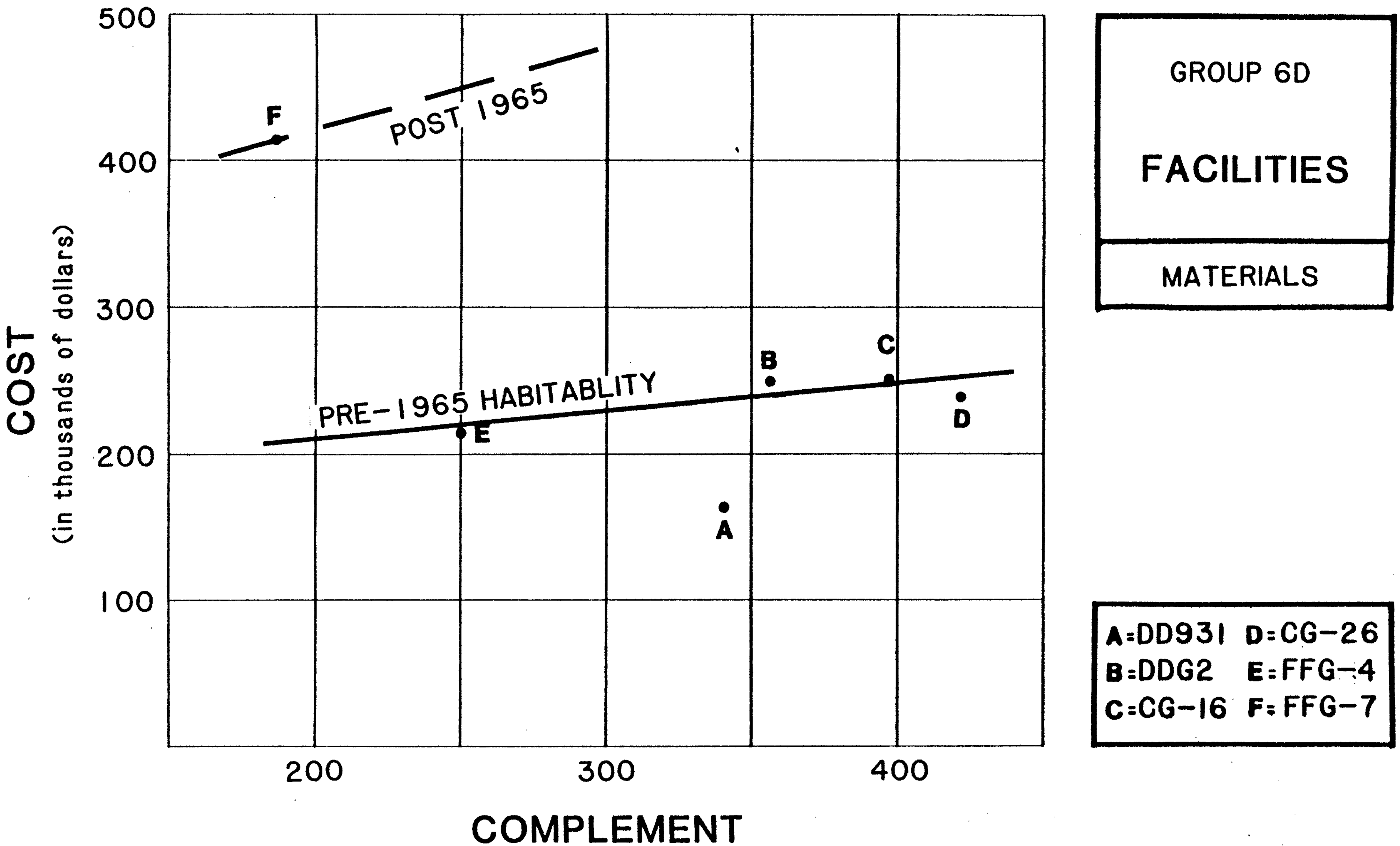
This group includes furnishings for living spaces, machinery spaces and medical spaces, and galley equipment.

MATERIAL FACTOR: The two algorithms for Group 6E material costs as a function of weight represent the change in habitability standards between the pre-1965 standards and the post-1965 habitability standards. Surprisingly, in this instance, cost as a function of complement has a low coefficient of determination. The upper line of the graph should be used for new designs as this represents such changes as larger clearances between bunks, more recreation room seating, and improved recreation facilities.

CER: $ = 7,130 WT + 250,000
Variable: Group 6E Weight
Application: Pre-1965 Habitability

CER: $ = 11,900 WT + 444,000
Variable: Group 6E Weight
Application: Post-1965 Habitability

LABOR FACTOR: For Group 6E, the independent variable of weight appears to be satisfactory for estimating man-hours with a single algorithm.



GROUP 6D
FACILITIES
MATERIALS
POST 1965
PRE-1965 HABITABLITY
COST (in thousands of dollars)
COMPLEMENT
500
400
300
200
100
200
300
400
A
B
C
D
E
F
A=DD931 D=CG-26
B=DDG2 E=FFG-4
C=CG-16 F=FFG-7


Figure 3-61

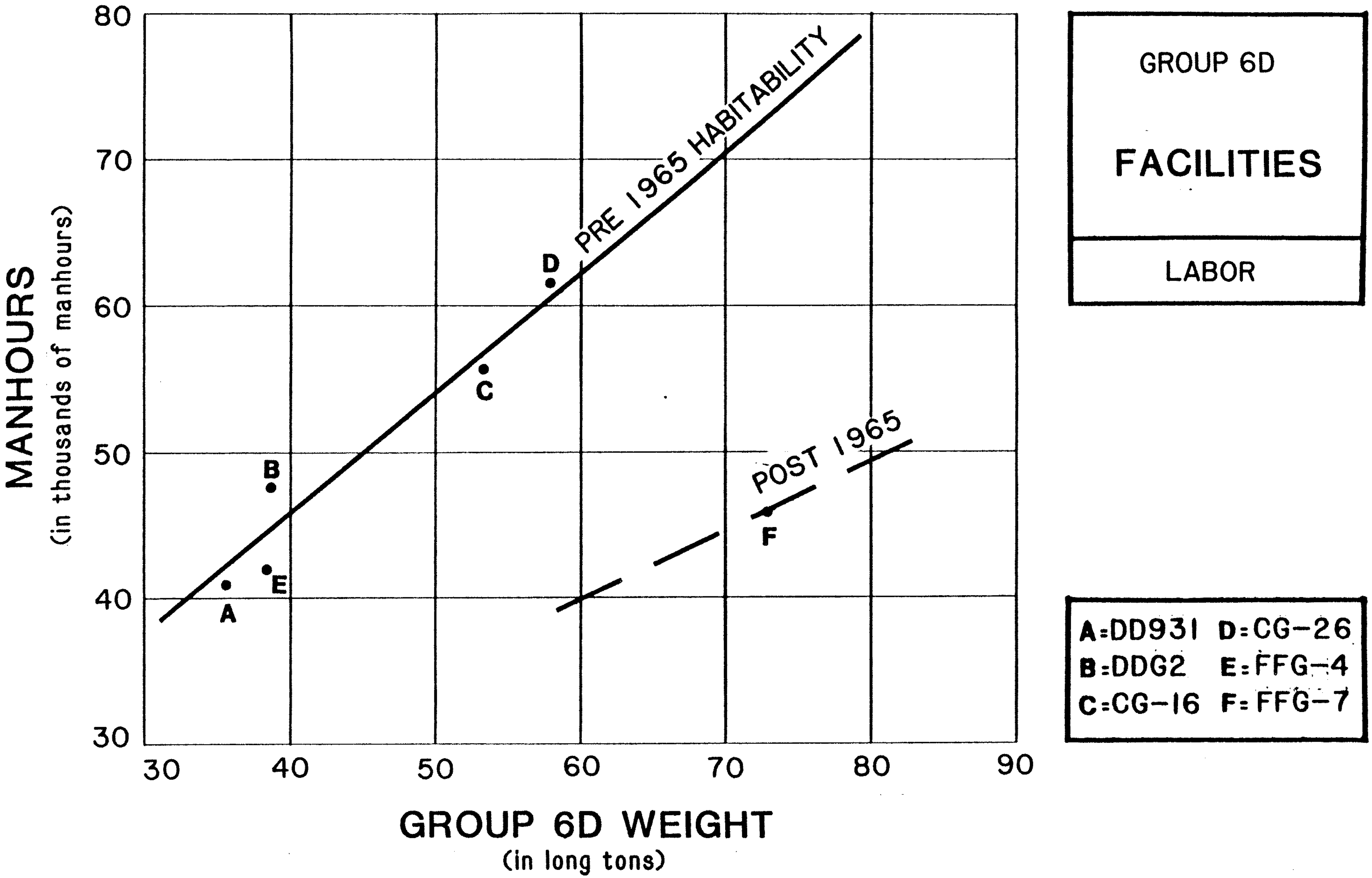

MANHOURS
(in thousands of manhours)
80
70
60
50
40
30
PRE 1965 HABITABILITY
POST 1965
A
B
C
D
E
F
30
40
50
60
70
80
90
GROUP 6D WEIGHT
(in long tons)
GROUP 6D
FACILITIES
LABOR
A=DD931 D=CG-26
B=DDG2 E=FFG-4
C=CG-16 F=FFG-7

Figure 3-62

CER: MH = 407 WT + 15,100

Variable: Group 6E Weight

Application: All

See Figures 3-63 and 3-64 for graphs of data points.

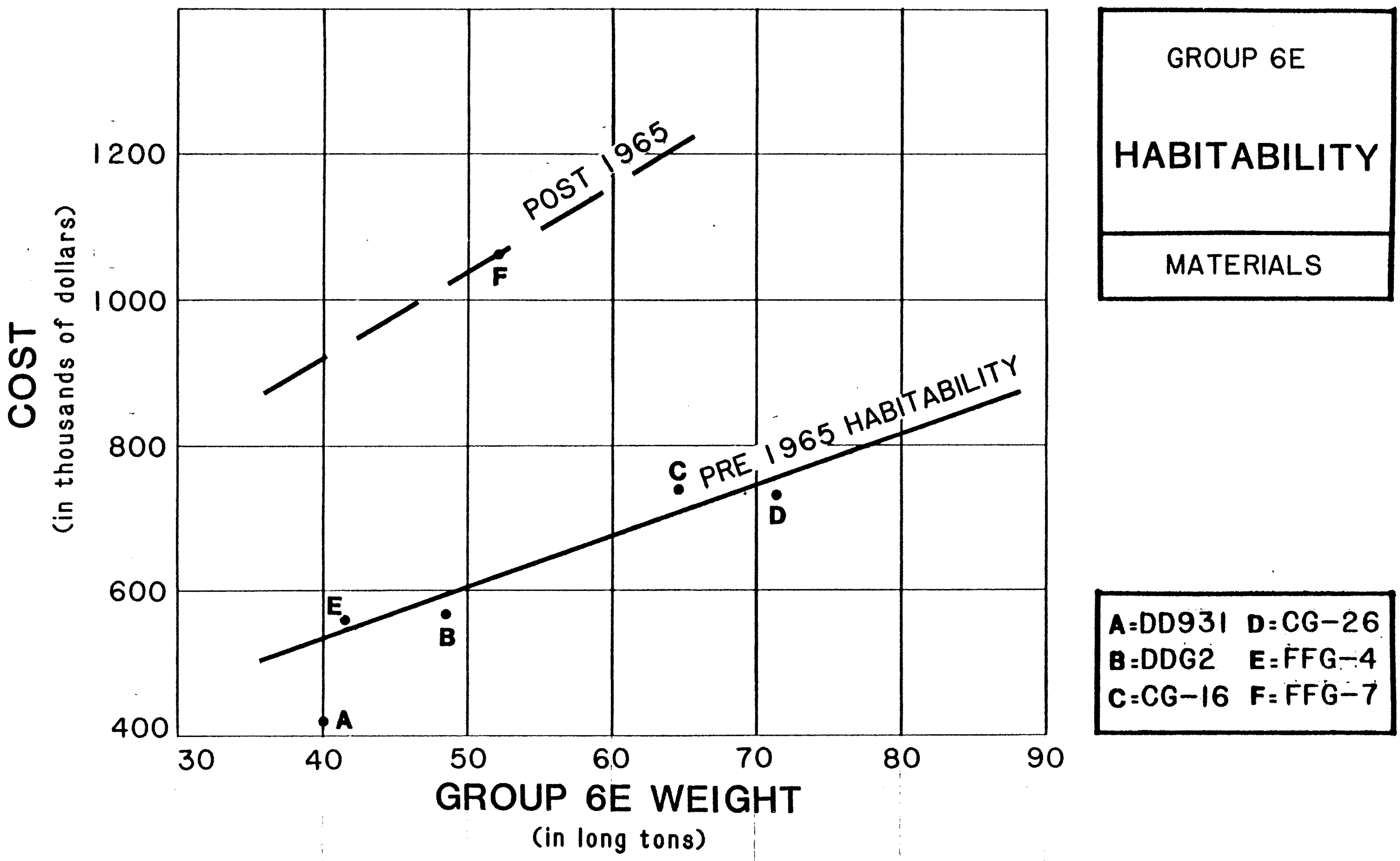
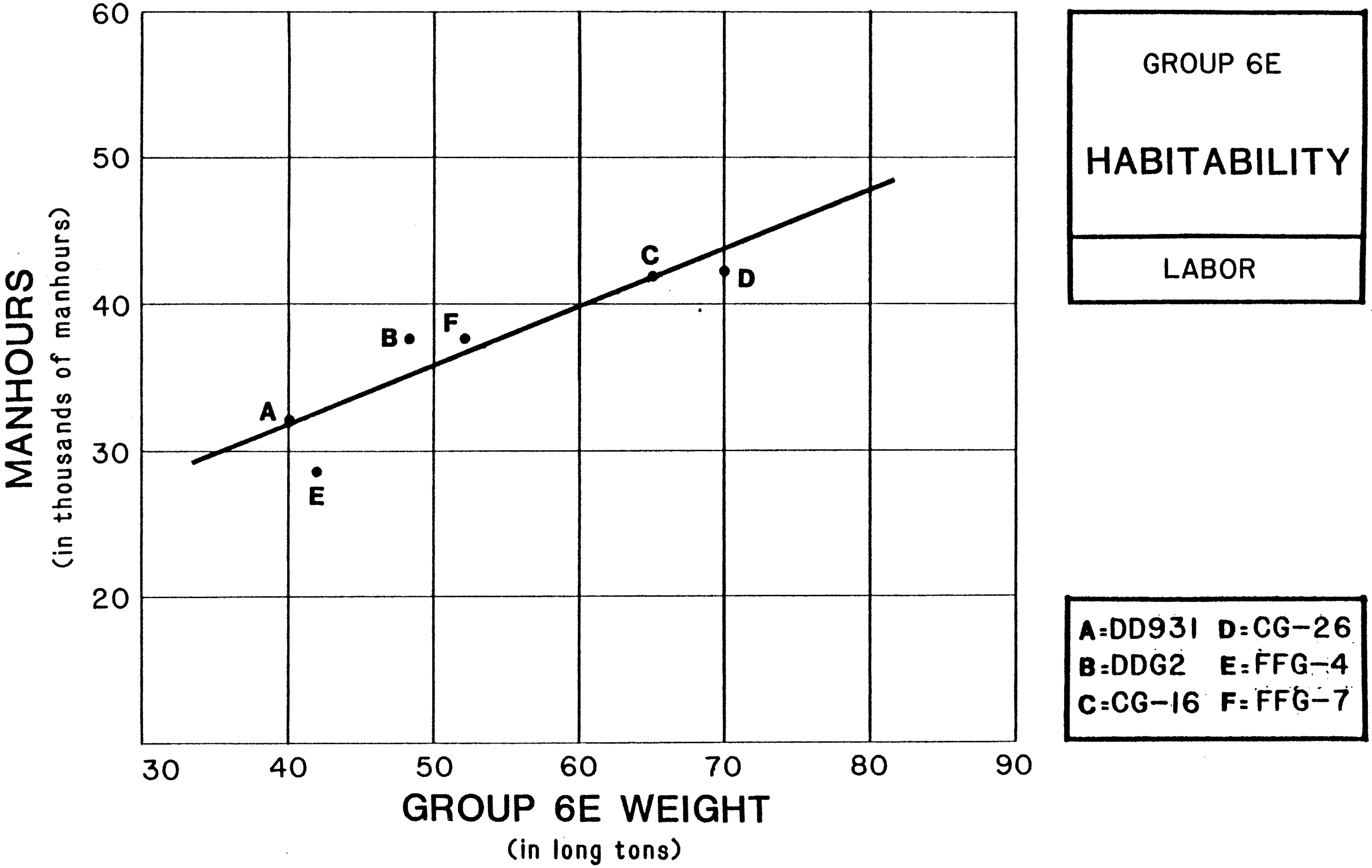

GROUP 6E
HABITABILITY
MATERIALS
COST
(in thousands of dollars)
1200
1000
800
600
400
30
40
50
60
70
80
90
GROUP 6E WEIGHT
(in long tons)
POST 1965
PRE 1965 HABITABILITY
A
B
C
D
E
F
A=DD931 D=CG-26
B=DDG2 E=FFG-4
C=CG-16 F=FFG-7

Figure 3-63



GROUP 6E
HABITABILITY
LABOR
MANHOURS
(in thousands of manhours)
GROUP 6E WEIGHT
(in long tons)
60
50
40
30
20
30
40
50
60
70
80
90
A
B
C
D
E
F
A=DD931 D=CG-26
B=DDG2 E=FFG-4
C=CG-16 F=FFG-7


Figure 3-64

### 3.4.7 Group 7 - Armament

This group includes only the installation of ordnance handling equipment, gun/missile systems, munitions stowage, etc.

MATERIAL FACTOR: Group 7 material costs are related to the weapons systems installed, the state-of-the-art in terms of system sophistication and complexity, and the function the ship is designed to perform. FFG-7 is somewhat representative of current practices where material costs are in the range of 3,000 to 6,000 dollars per ton (this is not including GFE). For a future ship design with VLS, the costs could be lower because of its modular nature and the lack of restrictions on the weapons alignment.

CER: $ = 1,970 WT - 293,000
Variable: Group 7 Weight
Application: Early Technology

CER: $ = 1,625 WT + 178,000
Variable: Group 7 Weight
Application: Current Technology

LABOR FACTOR: Group 7 man-hours appear to be a function of the group weight, and not dependent on the particular weapons systems involved or their complexity. This will also be affected by increased modularization.

CER: MH = 492.4 WT - 24,400
Variable: Group 7 Weight
Application: Current Technology

See Figures 3-65 and 3-66 for graphs of data points.

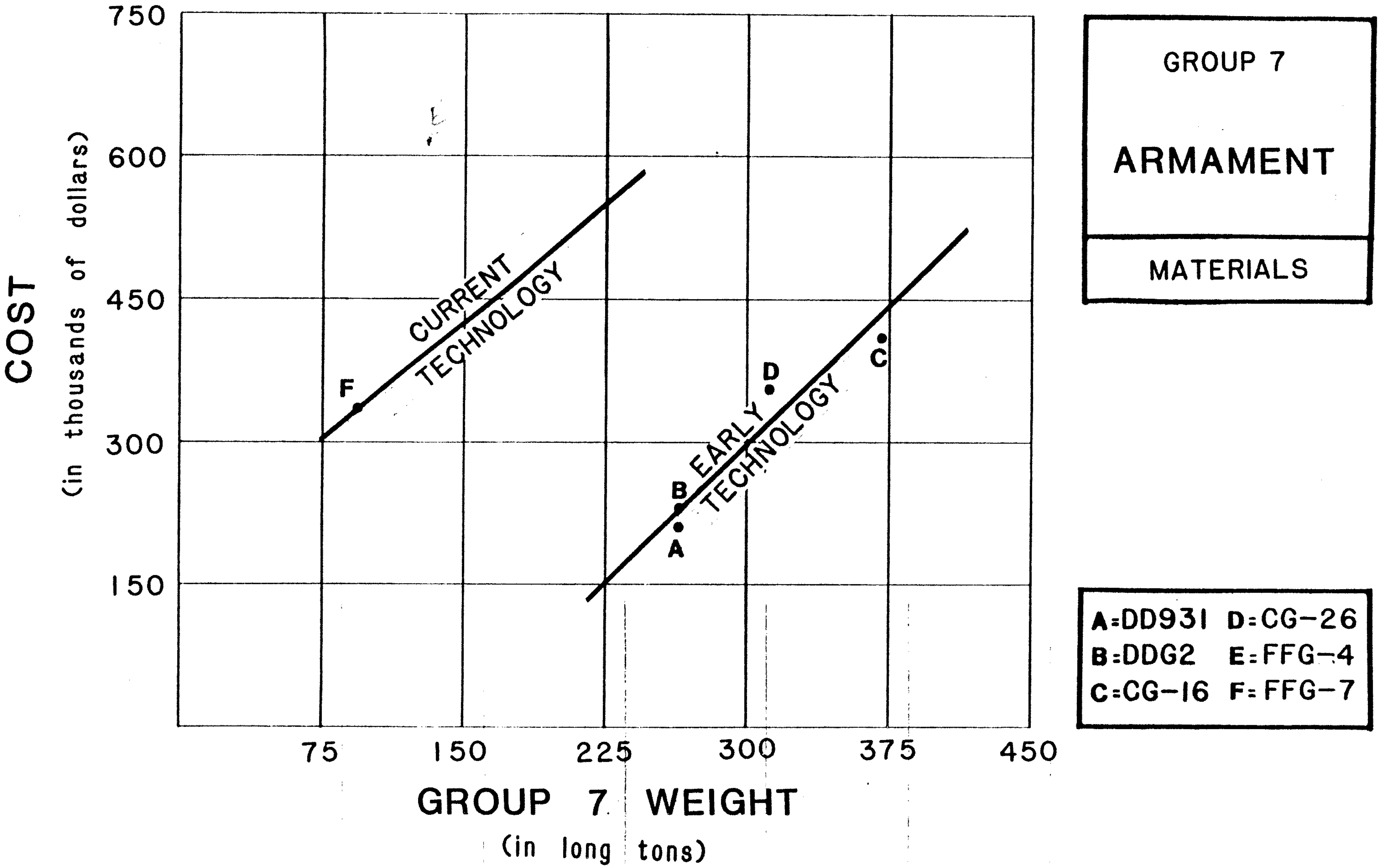

COST
(in thousands of dollars)
750
600
450
300
150
75
150
225
300
375
450
GROUP 7 WEIGHT
(in long tons)
CURRENT TECHNOLOGY
EARLY TECHNOLOGY
F
D
C
B
A
GROUP 7
ARMAMENT
MATERIALS
A=DD931 D=CG-26
B=DDG2 E=FFG-4
C=CG-16 F=FFG-7

Figure 3-65

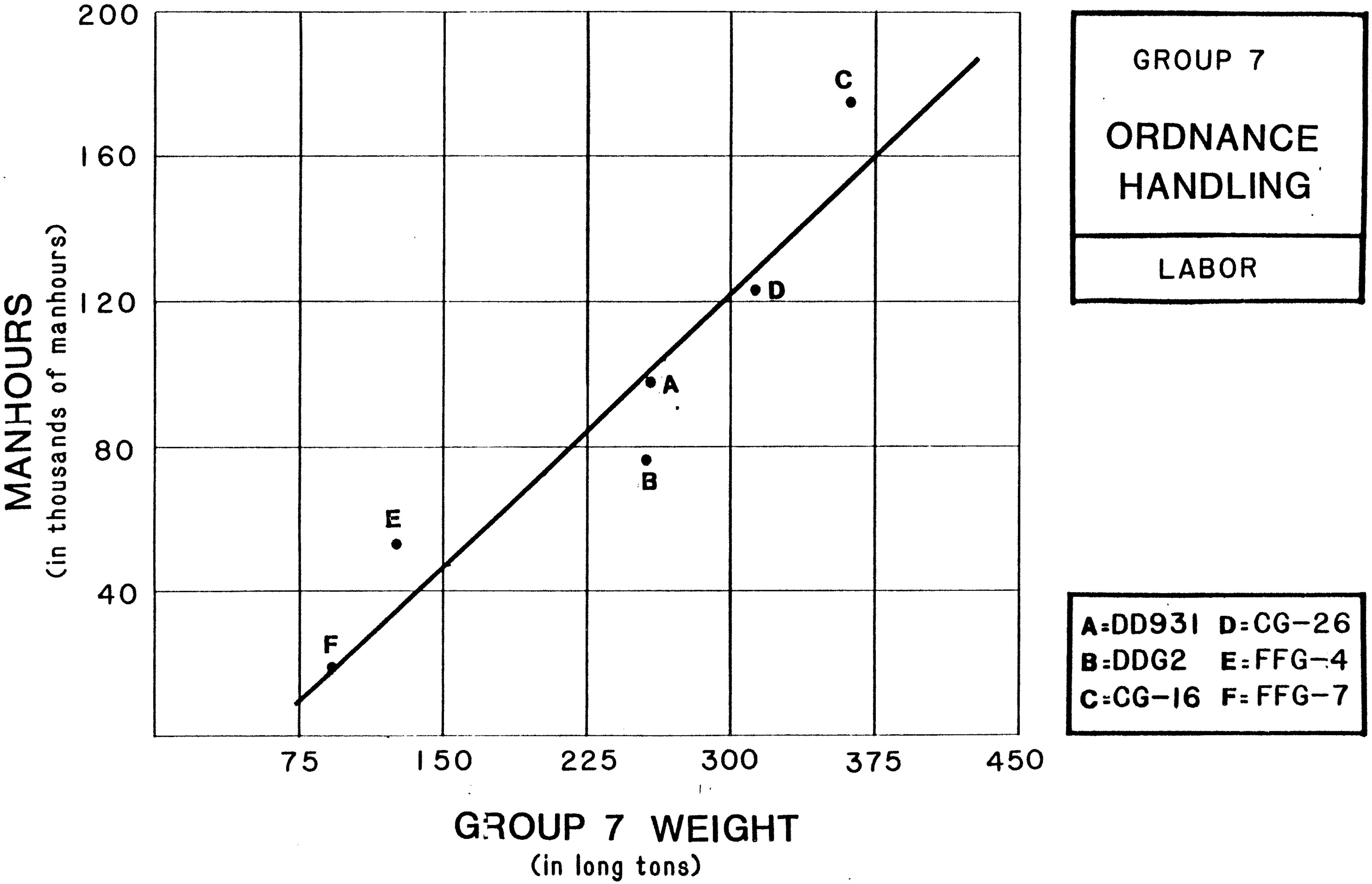

GROUP 7
ORDNANCE HANDLING
LABOR
MANHOURS
(in thousands of manhours)
200
160
120
80
40
75
150
225
300
375
450
GROUP 7 WEIGHT
(in long tons)
A
B
C
D
E
F
A=DD931 D=CG-26
B=DDG2 E=FFG-4
C=CG-16 F=FFG-7

Figure 3-66

## 3.5 Software

### 3.5.1 Design and Engineering Services - Group 8

Costs of shipyard labor and material required for the actual construction and delivery of the ship have been discussed in the preceding sections of this report. It is assumed in this model that detailed design plans already exist. There is no provision for the costs of preliminary, contract, or detail designs or for design related trade-off studies.

This section will discuss the means of communication used to inform the shipyard workers how to construct the product, i.e., the plans, material lists, and instructions that tell the workers how and what to build (defined as software in A Handbook of Shipyard Costs, Reference 16). Other than possible project participation, the first time the shipyard becomes involved with this software is at the end of the contract design phase. After "building" contract award, shipyard costs begin to accumulate for that vessel. Prior to 1970, these shipyard costs were in the following areas:

- Drawing Room - for processing drawings, requisitioning parts lists and catalog material, and yard liaison.
- Technical Department - for requisitioning purchased specification material, drawing approval, test agenda, launching, drydocking, damage control books, weight control, etc.
- Purchasing Department - for purchasing of material.
- Mold Loft - for lines fairing, layouts, and nesting.
- Miscellaneous - includes detail sketches for piping, electrical distribution, ventilation; special tools and patterns.

The hours and material costs for these software services in a U.S. shipyard are given below. It should be noted that these costs are considered as "non-recurring" and experience a very pronounced learning curve on the order of 50 percent.

Table 3.8. Software Costs Prior to 1970 (U)

| | Labor Hours | Material (1) |
|---|---|---|
| Drawing | 190,000 | $200,000 (2) |
| Technical Department | 60,000 | 40,000 |
| Purchasing Department | 90,000 | 75,000 (3) |
| Mold Loft | 98,000 | 30,000 |
| Miscellaneous | 45,000 | 110,000 |
| TOTAL: | 483,000 | $455,000 |

(1) Material dollars are assumed to be 1980 dollars.

(2) Material costs include reproduction, microfilm, mockups, and travel.

(3) Material costs are for travel.

By 1970, the U.S. Navy had begun to increase the software requirements that were to be imposed upon the shipyards. Full technical documentation was required for all equipment, including endurance and shock testing. (It should be noted that GFE related software costs such as combat system, test planning, etc., are not included.) This documentation then had to be integrated into the required U.S. Navy system. Program Managers' Offices (PMO) were required to oversee the program and keep the U.S. Navy posted on actual progress. Design Control and Configuration Management were introduced to assure that the changes were compatible with class requirements. These post 1970 costs are shown below and should be considered as added software costs for any U.S. lead ship of the size and type applicable to this cost model built after 1970.

Table 3.9. Added Software Costs for U.S. Navy Vessels After 1970 (U)

| | Labor Hours | Material[1][2] |
|---|---|---|
| Program Manager's Office | 72,000 | $ 90,000 |
| Integrated Logistics Support | 25,000 | 60,000 |
| Reliability, Maintainability, and Availability | 25,000 | 40,000 |
| Data Management | 30,000 | 15,000 |
| Producibility Management | 20,000 | 15,000 |
| Test and Evaluation | 30,000 | 25,000 |
| Integration Engineering | 65,000 | 200,000 |
| Configuration Management | 40,000 | 95,000 |
| TOTAL: | 307,000 | $540,000 |

(1) Material dollars are 1980 dollars - generally for travel.
(2) The above figures should be reduced to 50 percent for the first follow ship and to 20 - 25 percent for succeeding ships of the same class.

### 3.5.2 Construction Services - Group 9

By definition, Group 9 includes services required to support the construction of the vessel in the shipyard. It includes items such as launching, drydocking, trials, temporary utilities and services, material handling, staging, jigs and fixtures, etc. In addition, contract administration, detailed planning, direct travel costs, shop clerks freight for stores (bulk) material, secrity and fire protection, miscellaneous welding wire and brazing materials, and cutting, brazing, and heating gases have been added. After 1970, Group 9 will also include central planning, e.g., unit breakdown, work packaging, pre-outfitting, etc.

Within reasonable limits, these service costs are more closely proportional to the length of time the vessel is in the shipyard (from keel laying to delivery) than to the weight of the vessel. They are estimated at 16,000 labor hours per month and $45,500 material per month (1980) for the time period covered in this model. If shipyard building time is unknown, 30 months can be assumed for an FFG-7 type vessel.

# 4. CONCLUSIONS AND RECOMMENDATIONS

## 4.1 Basic Construction Cost

Basic construction cost, which is the portion of the Ship Construction, Navy (SCN) budget estimate (Table 3.1) developed using this model, amounts to only one fourth of the dollars that must be appropriated by Congress for each new ship. A 4 percent inaccuracy in the model cost prediction thus becomes only 1 percent in total ship cost. In addition, the rate of change in economic conditions affects cost estimates more substantially than the technical aspects of the cost model. The net result of these considerations should be high confidence in the model predictions for their intended use.

Where possible, the two-digit model should be used to determine basic construction costs since it is more sensitive to variations in characteristics of the ship.

## 4.2 Algorithms

The costs generated by this model are based upon a fixed range of U.S. frigates, destroyers and cruisers. For larger vessels that have the same basic characteristics as those described in this model, those vessels that would require extensions of the graphs, the mathematical equations may be used to estimate group costs. (Confidence in the accuracy of the algorithm will decrease with increasing extrapolation.)

The algorithms are recorded in terms of the result of each linear regressional analysis. They are modified to reflect three significant figures in most instances. The Total Basic Ship Construction Cost can be considered accurate to within twenty percent.

In some instances, the jump from the base trend line to the FFG-7 line is not so much indicative of new state-of-the-art items, but represents the lapse in continued naval ship construction with a jump in costs upon resumption of building naval vessels. This is characteristic of the BIW experience, but not necessarily of other shipyards. This effect can be seen in the FFG-4 on some of the labor curves. While constructing the FFG-4, BIW was at a high point in its learning curve having constructed many destroyers in a relatively short time frame with a steady state of experience versus learning. Future ships, when used to test the new technology lines for ship costs, will greatly enhance the predictive value of this model. It may be that the slopes of the algorithms need not be proportional to each other, but instead, parallel in that a constant demand for shipbuiding could stabilize erratic price changes.

## 4.3 SWBS/BSCI Data

The difficulty of acquiring returned costs from shipyards in the SWBS structure should continue to be addressed by U.S. Navy offices. Since imposing constraints on shipyard record keeping is not likely to be effective and is likely to be expensive, it would be more appropriate to try to understand, analyze, and reorganize data that is available. Particular problem areas encountered in this study were relatively few, but very important in impact on total ship cost. Shipyards other than BIW would most likely present other problem areas due to their unique recording practices and to the age of their pertinent data.

## 5. REFERENCES


1. NAVSEAINST 7300.14, June 1980.

2. International Maritime Associates, Inc., A Study of Ship Acquisition Cost Estimating in the Naval Sea Systems Command, Naval Sea Systems Command, Contract N00024-77-C-2013, 1977.

3. SWBS, NAVSEA 0900-LP-039-9010, NAVSEC, August 1977.

4. BSCI NAVSHIPS 0902-002-2000, February 1965.

5. Design of Naval Surface Combatant Ships, N00024-77-C-4754 (G&C No. 18450-508), September 1979.

6. Gibbs & Cox, Inc., MID-MIX Design Strategy, Ship Design Fractions, Naval Sea Systems Command, Contract No. N00024-77-C-4754, 1980.

7. Gibbs & Cox, Inc., "General Information on Destroyer Weight Analyses (U)," Naval Ship Engineering Center, Contract No. N00024-76-C-4450, 1979.

8. Naval Sea Systems Command, Guided Missile Destroyer, DDG-47 Class, Master Equipment List, 1977.

9. Office of the Chief of Naval Operations, DDG-47 Class Top Level Requirements (U), OPNAVINST C9010.314, 1976.

10. Gibbs & Cox, Inc., Evaluation of Major Drivers in Frigate Design (U), Naval Ship Engineering Center Contract No. N00024-77-C04754, 1980.

11. Gibbs & Cox, Inc., Cost Analysis of Major Soviet Combatant Vessels, Naval Sea Systems Command, Contract No. 77-N-229700-000, 1979.

12. R.P. Johnson, H.P. Rumble, J.A. Pennypacker, and T.M. Burkholz, Determination of Weight, Volume, and Construction Costs for Navy Combatant and Auxiliary Ships, Rand Corp. Memo No. RM-5686-PR, April 1969.

13. NAVSHIPS Cost Model - RMC Report CR-058, January 1969.

14. D.M. Hernon and R.R. McCumber, Jr., Estimation of Destroyer Type Naval Ship Procurement Costs, U.S. Naval Postgraduate School, Monterey, California, Master's Degree Thesis, 1973.

15. Shipbuilders Council of America, Statistical Quarterly, Third Quarter, 1980.

## 5. REFERENCES (Continued)

16. Edward M. Kaitz & Associates, Inc., Building Naval Vessels: A Handbook of Shipyard Costs, Department of the Navy Contract No. N00014-79-C-0521, Report 80-1, 1980.

# APPENDIX A

# PERCENTAGE WEIGHT DISTRIBUTION

TABLE A-1
APPENDIX A

PERCENTAGE OF LIGHT SHIP WEIGHT (IN COST GROUP; WITHIN WEIGHT GROUP)

| COST GROUP | | DD 931 | | DDG 2 | | CG 16 | | CG 26 | | FFG 4 | | FFG 7 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | A | 77 | | 75 | | 82 | | 80 | | 80 | | 75 | |
| | B | 7 | | 9 | | 6 | | 6 | | 6 | | 9 | |
| | C | 10 | | 10 | | 7 | | 7 | | 8 | | 11 | |
| | D | 6 | | 6 | | 5 | | 7 | | 6 | | 5 | |
| SUBTOTAL: | | | 36 | | 37 | | 46 | | 47 | | 46 | | 46 |
| 2 | A | 70 | | 68 | | 66 | | 66 | | 59 | | 46 | |
| | B | 13 | | 15 | | 19 | | 19 | | 19 | | 30 | |
| | C | 5 | | 5 | | 6 | | 6 | | 7 | | 10 | |
| | D | 12 | | 12 | | 9 | | 9 | | 15 | | 14 | |
| SUBTOTAL: | | | 30 | | 26 | | 18 | | 17 | | 15 | | 10 |
| 3 | A | 45 | | 45 | | 47 | | 48 | | 51 | | 50 | |
| | B | 55 | | 55 | | 53 | | 52 | | 49 | | 50 | |
| SUBTOTAL: | | | 4 | | 4 | | 4 | | 4 | | 4 | | 7 |
| 4 | A | 42 | | 24 | | 21 | | 21 | | 20 | | 30 | |
| | B | 58 | | 76 | | 79 | | 79 | | 80 | | 70 | |
| SUBTOTAL: | | | 3 | | 5 | | 7 | | 7 | | 6 | | 4 |
| 5 | A | 23 | | 22 | | 24 | | 23 | | 23 | | 24 | |
| | B | 54 | | 55 | | 55 | | 56 | | 45 | | 54 | |
| | C | 13 | | 10 | | 10 | | 9 | | 14 | | 10 | |
| | D | 10 | | 13 | | 11 | | 12 | | 18 | | 12 | |
| SUBTOTAL: | | | 11 | | 12 | | 11 | | 11 | | 14 | | 17 |
| 6 | A | 14 | | 15 | | 14 | | 15 | | 15 | | 9 | |
| | B | 17 | | 18 | | 18 | | 16 | | 14 | | 21 | |
| | C | 32 | | 35 | | 35 | | 38 | | 38 | | 30 | |
| | D | 18 | | 14 | | 15 | | 14 | | 16 | | 23 | |
| | E | 19 | | 18 | | 18 | | 17 | | 17 | | 17 | |
| SUBTOTAL: | | | 7 | | 8 | | 7 | | 8 | | 10 | | 12 |
| 7 | SUB-TOTAL | | 9 | | 8 | | 7 | | 6 | | 5 | | 4 |
| TOTAL | | | 100 | | 100 | | 100 | | 100 | | 100 | | 100 |

TABLE A-2

PERCENTAGE OF LIGHT SHIP WEIGHT (IN COST GROUP)

| COST GROUP | | SAMPLE SHIPS DD 931 | DDG 2 | CG 16 | CG 26 | FFG 4 | FFG 7 | | OTHER SHIPS DDG 40 | FF 1052 | DD 963 | DDG 993 | CG 47 | DDGX | % AVG. 12 SHIPS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | A | 28 | 28 | 37 | 38 | 37 | 35 | | | | | | | | |
| | B | 3 | 3 | 3 | 3 | 3 | 4 | | | | | | | | |
| | C | 4 | 4 | 3 | 3 | 4 | 5 | | | | | | | | |
| | D | 2 | 2 | 2 | 3 | 3 | 2 | | | | | | | | |
| SUBTOTAL: | | 36 | 37 | 46 | 47 | 46 | 46 | | 42 | 47 | 53 | 51 | 50 | 50 | 45.9 |
| 2 | A | 21 | 18 | 12 | 11 | 9 | 5 | | | | | | | | |
| | B | 4 | 4 | 3 | 3 | 3 | 3 | | | | | | | | |
| | C | 1 | 1 | 1 | 1 | 1 | 1 | | | | | | | | |
| | D | 4 | 3 | 2 | 2 | 2 | 1 | | | | | | | | |
| SUBTOTAL: | | 30 | 26 | 18 | 17 | 15 | 10 | | 22 | 15 | 13 | 11 | 10 | 13 | 16.9 |
| 3 | A | 2 | 2 | 2 | 2 | 2 | 4 | | | | | | | | |
| | B | 2 | 2 | 2 | 2 | 2 | 4 | | | | | | | | |
| SUBTOTAL: | | 4 | 4 | 4 | 4 | 4 | 7 | | 4 | 4 | 5 | 5 | 5 | 7 | 4.8 |
| 4 | A | 1 | 1 | 1 | 1 | 1 | 1 | | | | | | | | |
| | B | 2 | 4 | 6 | 6 | 5 | 3 | | | | | | | | |
| SUBTOTAL: | | 3 | 5 | 7 | 7 | 6 | 4 | | 5 | 7 | 6 | 6 | 7 | 6 | 5.7 |
| 5 | A | 3 | 3 | 3 | 3 | 3 | 4 | | | | | | | | |
| | B | 6 | 7 | 6 | 6 | 6 | 9 | | | | | | | | |
| | C | 1 | 1 | 1 | 1 | 2 | 2 | | | | | | | | |
| | D | 1 | 1 | 1 | 1 | 3 | 2 | | | | | | | | |
| SUBTOTAL: | | 11 | 12 | 11 | 11 | 14 | 17 | | 12 | 13 | 13 | 14 | 14 | 13 | 13.0 |
| 6 | A | 1 | 1 | 1 | 1 | 1 | 1 | | | | | | | | |
| | B | 1 | 1 | 1 | 1 | 1 | 3 | | | | | | | | |
| | C | 2 | 3 | 2 | 3 | 4 | 4 | | | | | | | | |
| | D | 1 | 1 | 1 | 1 | 2 | 3 | | | | | | | | |
| | E | 1 | 1 | 1 | 1 | 2 | 2 | | | | | | | | |
| SUBTOTAL: | | 7 | 8 | 7 | 8 | 10 | 12 | | 8 | 9 | 7 | 8 | 8 | 8 | 8.3 |
| 7 | SUB-TOTAL | 9 | 8 | 7 | 6 | 5 | 4 | | 7 | 5 | 3 | 5 | 5 | 2 | 5.5 |
| TOTAL | | 100 | 100 | 100 | 100 | 100 | 100 | | 100 | 100 | 100 | 100 | 100 | 100 | 100 |

# APPENDIX B

# WEIGHT ALGORITHMS

## APPENDIX B
## WEIGHT ALGORITHMS

COST GROUP: 1A

| SWBS NO. | DESCRIPTION | WEIGHT ALGORITHMS |
|---|---|---|
| 111 | SHELL PLATING, SURF. SHIP AND SUBMARINE PRESS. HULL | $W = 2.77$ (HULL VOLUME) $(FT^3) \times 10^{-3}$ (INCLUDES ALL 3-DIGIT ELEMENTS ON THIS PAGE PLUS SOME OF GROUP 1D WEIGHTS, e.g., 161, 163, 167) |
| 113 | INNER BOTTOM | |
| 114 | SHELL APPENDAGES | |
| 115 | STANCHIONS | |
| 116 | LONGIT. FRAMING, SURF. SHIP AND SUBMARINE PRESS. HULL | |
| 117 | TRANSV. FRAMING, SURF. SHIP AND SUBMARINE PRESS. HULL | |
| 121 | LONGITUDINAL STRUCTURAL BULKHEADS | |
| 122 | TRANSVERSE STRUCTURAL BULKHEADS | |
| 123 | TRUNKS AND ENCLOSURES | |
| 124 | BULKHEADS IN TORPEDO PROTECTION SYSTEM | |
| 131 | MAIN DECK | |
| 132 | 2ND DECK | |
| 133 | 3RD DECK | |
| 134 | 4TH DECK | |
| 135 | 5TH DECK AND DECKS BELOW | |
| 141 | 1ST PLATFORM | |
| 142 | 2ND PLATFORM | |
| 143 | 3RD PLATFORM | |
| 144 | 4TH PLATFORM | |
| 145 | 5TH PLATFORM | |
| 149 | FLATS | |
| 166 | SPONSONS | |

COST GROUP: 1B

| SWBS NO. | DESCRIPTION | WEIGHT ALGORITHMS |
|---|---|---|
| 151 | DECKHOUSE STRUCTURE TO FIRST LEVEL | $W = 9$ (SUPERSTRUCTURE VOLUME ($FT^3$)) x $10^{-4}$ IF ALUMINUM, NO GAS TURBINES<br>$W = 15$ (SUPERSTRUCTURE VOLUME ($FT^3$)) x $10^{-4}$ IF STEEL<br>$W = 8.5$ (SUPERSTRUCTURE VOLUME ($FT^3$)) x $10^{-4}$ IF GAS TURBINE NO HELOS<br>OR |
| 152 | 1ST DECKHOUSE LEVEL | $W = 7.5$ (SUPERSTRUCTURE VOLUME ($FT^3$)) x $10^{-4}$ IF GAS TURBINE 2 HELOS |
| 153 | 2ND DECKHOUSE LEVEL | (INCLUDES ALL 3-DIGIT ELEMENTS ON THIS PAGE AS WELL AS ELEMENTS 16~~7~~2 AND 168 OF GROUP 1D) |
| 154 | 3RD DECKHOUSE LEVEL | |
| 155 | 4TH DECKHOUSE LEVEL | |
| 156 | 5TH DECKHOUSE LEVEL | |
| 157 | 6TH DECKHOUSE LEVEL | |
| 158 | 7TH DECKHOUSE LEVEL | |
| 159 | 8TH DECKHOUSE LEVEL AND ABOVE | |
| 164 | BALLISTIC PLATING | |

COST GROUP: 1C

| SWBS NO. | DESCRIPTION | WEIGHT ALGORITHMS |
|---|---|---|
| 182 | PROPULSION PLANT FOUNDATIONS | W = .065(WT OF COST GROUPS 2A,+2C,+2D) IF STEAM, OR W = .166 (WT OF SWBS GROUP 2) + 1.5 IF GAS TURBINE |
| 183 | ELECTRIC PLANT FOUNDATIONS | W = .1308 (WT OF SWBS GROUP 3) |
| 184 | COMMAND AND SURVEILLANCE FOUNDATIONS | W = .08214 (WT OF SWBS GROUP 4) NOTE: EXCLUDE SONAR WATER |
| 185 | AUXILIARY SYSTEMS FOUNDATIONS | W = .10 (WT OF SWBS GROUP 5) |
| 186 | OUTFIT AND FURNISHINGS FOUNDATIONS | W = .063 (WT OF SWBS GROUP 6) |
| 187 | ARMAMENT FOUNDATIONS | W = .075 (WT OF SWBS GROUP 7) |

## APPENDIX B
## WEIGHT ALGORITHMS (Continued)

COST GROUP: 1D

| SWBS NO. | DESCRIPTION | WEIGHT ALGORITHMS |
|---|---|---|
| 161 | STRUCTURAL CASTINGS, FORGINGS, AND EQUIV. WELDMENTS | |
| 162 | STACKS AND MACKS (COMBINED STACK AND MAST) | |
| 163 | SEA CHESTS | |
| 165 | SONAR DOMES | IF SQS-56 W = 1.0<br>SQS-23 W = 40.0<br>SQS-53A W = 75.0<br>SQS-26 |
| 167 | HULL STRUCTURAL CLOSURES | |
| 168 | DECKHOUSE STRUCTURAL CLOSURES | |
| 169 | SPECIAL PURPOSE CLOSURES AND STRUCTURES | W = .833 (TOTAL SHIP VOLUME ($FT^3$)) x $10^{-5}$ |
| 171 | MASTS, TOWERS, TETRAPODS | W = 2.73 (TOTAL SHIP VOLUME ($FT^3$)) x $10^{-5}$ IF ENCLOSED TOWERS |
| 172 | KINGPOSTS AND SUPPORT FRAMES | OR W = 1.31 (TOTAL SHIP VOLUME ($FT^3$)) x $10^{-5}$ IF OPEN LATTICE |
| | | NOTE: OTHER WEIGHTS INCLUDED IN COST GROUP 1A OR 1B ESTIMATES. |
| | | NOTE: WEIGHTS NOT INCLUDED AT ALL IN THIS COST MODEL<br>x 98 WATER<br>x 99 REPAIR PARTS |

APPENDIX B
WEIGHT ALGORITHMS (Continued)

COST GROUP: 2A

| SWBS NO. | DESCRIPTION | WEIGHT ALGORITHMS |
|---|---|---|
| 221 | PROPULSION BOILERS | |
| 222 | GAS GENERATORS | |
| 223 | MAIN PROPULSION BATTERIES | |
| 224 | MAIN PROPULSION FUEL CELLS | |
| 231 | PROPULSION STEAM TURBINES | |
| 232 | PROPULSION STEAM ENGINES | |
| 233 | PROPULSION INTERNAL COMBUSTION ENGINES | |
| 234 | PROPULSION GAS TURBINES | |
| 235 | ELECTRIC PROPULSION | |
| 236 | SELF-CONTAINED PROPULSION SYSTEMS | |
| 237 | AUXILIARY PROPULSION DEVICES | |
| 241 | PROPULSION REDUCTION GEARS | |
| 242 | PROPULSION CLUTCHES AND COUPLINGS | |
| 253 | MAIN STEAM PIPING SYSTEM | |
| 254 | CONDENSERS AND AIR EJECTORS | |
| 255 | FEED AND CONDENSATE SYSTEM | |

# APPENDIX B
## WEIGHT ALGORITHMS (Continued)

COST GROUP: 2B

| SWBS NO. | DESCRIPTION | WEIGHT ALGORITHMS |
|---|---|---|
| 243 | PROPULSION SHAFTING | $W = (0.4464)(25.2 + (20.16)[SHP/(2 \times RPM)]^{2/3})(LENGTH) \times 10^{-3}$<br>WHERE:<br>SHP = TOTAL SHIP HORSEPOWER<br>RPM = RPM OF PROPELLER<br>L = SHIP LENGTH |
| 244 | PROPULSION SHAFT BEARINGS | $W = 0.15\ (W_{243} + W_{245})$ FOR TWIN SHAFT SHIPS |
| 245 | PROPULSORS | $W = (2)(68.89 + [((1.0940-0.018619D_p)\ D_p -15.36)D_p])$<br>WHERE:<br>$D_p$ = PROPELLER DIAMETER = (LENGTH) + 48 (DRAFT)/75 |
| 246 | PROPULSOR SHROUDS AND DUCTS | |

APPENDIX B
WEIGHT ALGORITHMS (Continued)

COST GROUP: 2C

| SWBS NO. | DESCRIPTION | WEIGHT ALGORITHMS |
| --- | --- | --- |
| 251 | COMBUSTION AIR SYSTEM | |
| 259 | UPTAKES (INNER CASING) | |

APPENDIX B
WEIGHT ALGORITHMS (Continued)

COST GROUP: 2D

| SWBS NO. | DESCRIPTION | WEIGHT ALGORITHMS |
|---|---|---|
| 252 | PROPULSION CONTROL SYSTEM | |
| 256 | CIRCULATING AND COOLING SEA WATER SYSTEM | |
| 258 | H.P. STEAM DRAIN SYSTEM | |
| 261 | FUEL SERVICE SYSTEM | |
| 262 | MAIN PROPULSION LUBE OIL SYSTEM | |
| 264 | LUBE OIL FILL, TRANSFER, AND PURIFICATION | |

# APPENDIX B
## WEIGHT ALGORITHMS (Continued)

COST GROUP: 3A

| SWBS NO. | DESCRIPTION | WEIGHT ALGORITHMS |
|---|---|---|
| 311 | SHIP SERVICE POWER GENERATION | IF TURBINES<br>W = .027 (KW x N)<br><br>IF 900 RPM Diesel Generators<br>W = [0.02011(KW) + 5.33] x N<br><br>IF 1200 RPM Diesel Generators<br>W = [0.01492(KW) + 4.50] x N<br><br>IF 1800 RPM Diesel Generators<br>W = [0.01382(KW) + 1.51] x N |
| 312 | EMERGENCY GENERATORS | W = 0 |
| 314 | POWER CONVERSION EQUIPMENT | W = 20.6 (400 Hz CONVERTER CAPACITY (KW)) x $10^{-6}$ + 0.37 (NO. OF HELICOPTERS) + .0639 (TOTAL SHIP VOLUME ($FT^3$)) x $10^{-5}$ + 0.96 |
| 341 | SSTG LUBE OIL | W = 0 |
| 342 | DIESEL SUPPORT SYSTEMS | IF JACKET WATER WASTE HEAT SYSTEM<br>W = 0.4 x (WEIGHT OF SWBS GROUP 311) + (3.57 x N)<br><br>NO WASTE HEAT SYSTEM<br>W = 0.4 x (W311) |
| 343 | TURBINE SUPPORT SYSTEMS | W = 0<br><br>WHERE:<br><br>KW = RATED GENERATOR CAPACITY<br>N = NUMBER OF GENERATORS |

APPENDIX B
WEIGHT ALGORITHMS (Continued)

COST GROUP: 3B

| SWBS NO. | DESCRIPTION | WEIGHT ALGORITHMS |
|---|---|---|
| 313 | BATTERIES AND SERVICE FACILITIES | W = 1.56 |
| 321 | SHIP SERVICE POWER CABLE | W = 3.45 (TOTAL SHIP VOLUME ($FT^3$)) x $10^{-5}$ + .00463 (GENERATING CAPACITY (KW)) |
| 322 | EMERGENCY POWER CABLE SYSTEM | W = 0 |
| 323 | CASUALTY POWER CABLE SYSTEM | W = 2.17 (LWL x BEAM) x $10^{-4}$ - 2.83 |
| 324 | SWITCHGEAR AND PANELS | W = 2.35 (TOTAL SHIP VOLUME ($FT^3$)) x $10^{-5}$ + .00317 (GENERATING CAPACITY (KW)) |
| 331 | LIGHTING DISTRIBUTION | W = 1.827 (TOTAL SHIP VOLUME ($FT^3$)) x $10^{-5}$ - 1.24 |
| 332 | LIGHTING FIXTURES | W = 1.346 (TOTAL SHIP VOLUME ($FT^3$)) x $10^{-5}$ - 0.65 |

## APPENDIX B
## WEIGHT ALGORITHMS (Continued)

COST GROUP: 4A

| SWBS NO. | DESCRIPTION | WEIGHT ALGORITHMS |
|---|---|---|
| 421 | NON-ELECTRICAL/ELECTRONIC NAVIGATION AIDS | W = 0.57 |
| 422 | ELECTRICAL NAVIGATION AIDS (INCL NAVIG. LIGHTS) | W = 0.78 + 1.69 (IF HELICOPTER EQUIPPED) |
| 423 | ELECTRONIC NAVIGATION SYSTEMS, RADIO | W = 0.92 |
| 424 | ELECTRONIC NAVIGATION SYSTEMS, ACOUSTICAL | W = 0.22 |
| 426 | ELECTRICAL NAVIGATION SYSTEMS | W = 2.49 |
| 427 | INERTIAL NAVIGATION SYSTEMS | |
| 428 | NAVIGATION CONTROL MONITORING | |
| 431 | SWITCHBOARDS FOR I.C. SYSTEMS | W = 0.17 (NO. OF FIRE CONTROL SYSTEM + NO. OF RADAR) + 0.53 |
| 432 | TELEPHONE SYSTEMS | W = 1.614 (TOTAL SHIP VOLUME ($FT^3$)) x $10^{-5}$ + 0.0169 (MANNING) - 8.00 |
| 433 | ANNOUNCING SYSTEMS | W = 0.45 (TOTAL SHIP VOLUME ($FT^3$)) x $10^{-5}$ |
| 434 | ENTERTAINMENT AND TRAINING SYSTEMS | W = 0.18 (TOTAL SHIP VOLUME ($FT^3$)) x $10^{-5}$ - 0.38 |
| 435 | VOICE TUBES AND MESSAGE PASSING SYSTEMS | W = 0.19 |
| 436 | ALARM, SAFETY, AND WARNING SYSTEMS | W = 0.22 (TOTAL SHIP VOLUME ($FT^3$)) x $10^{-5}$ + 0.055 (NO. OF GENERATORS) + 8.36 x (PAYLOAD POWER (MW)) x $10^{-5}$ + 0.26 |
| 437 | INDICATING, ORDER, AND METERING SYSTEMS | W = 3.87 (NO. OF SHAFTS) - 2.19 |
| 438 | INTEGRATED CONTROL SYSTEMS | W = 1.01 (NO. OF SHAFTS) - 0.57 |
| 439 | RECORDING AND TELEVISION SYSTEMS | |
| 443 | VISUAL AND AUDIBLE SYSTEMS | W = 0.38 |
| 473 | TORPEDO DECOYS | W = 1.44 (WEIGHT OF GFE IN 473) |
| 474 | DECOYS (OTHER) | W = 1.07 (WEIGHT OF GFE IN 474) |
| 475 | DEGAUSSING | W = 4.6 (TOTAL SHIP VOLUME ($FT^3$)) x $10^{-5}$ - 9.50 |
| 476 | MINE COUNTERMEASURES | |
| 491 | ELECTRONIC TEST, CHECKOUT, AND MONITORING EQUIPMENT | W = WEIGHT OF GFE IN 491 |
| 492 | FLIGHT CONTROL AND INSTRUMENT LANDING SYSTEMS | |
| 493 | NON COMBAT DATA PROCESSING SYSTEMS | |
| 494 | METEOROLOGICAL SYSTEMS | |
| 495 | SPECIAL PURPOSE INTELLIGENCE SYSTEMS | |

APPENDIX B
WEIGHT ALGORITHMS (Continued)

COST GROUP: 4B

| SWBS NO. | DESCRIPTION | WEIGHT ALGORITHMS |
|---|---|---|
| 411 | DATA DISPLAY GROUP | W = 1.38 (WEIGHT OF GFE IN 411) |
| 412 | DATA PROCESSING GROUP | W = 1.29 (WEIGHT OF GFE IN 412) |
| 413 | DIGITAL DATA SWITCHBOARDS | W = 1.94 (WEIGHT OF GFE IN 413) |
| 414 | INTERFACE EQUIPMENT | W = 1.43 (WEIGHT OF GFE IN 414) |
| 415 | DIGITAL DATA COMMUNICATIONS | |
| 417 | COMMAND AND CONTROL ANALOG SWITCHBOARDS | |
| 441 | RADIO SYSTEMS | W = 1.34 (WEIGHT OF GFE IN 441) |
| 442 | UNDERWATER SYSTEMS | W = 0.22 |
| 444 | TELEMETRY SYSTEMS | |
| 445 | TTY AND FACSIMILE SYSTEMS | W = 1.12 (WEIGHT OF GFE IN 445) |
| 446 | SECURITY EQUIPMENT SYSTEMS | W = 1.39 (WEIGHT OF GFE IN 446) |
| 451 | SURFACE SEARCH RADAR | W = 1.88 (WEIGHT OF GFE IN 451) |
| 452 | AIR SEARCH RADAR (2D) | W = 1.20 (WEIGHT OF GFE IN 452) |
| 453 | AIR SEARCH RADAR (3D) | |
| 454 | AIRCRAFT CONTROL APPROACH RADAR | |
| 455 | IDENTIFICATION SYSTEMS (IFF) | W = 1.29 (WEIGHT OF GFE IN 455) |
| 456 | MULTIPLE MODE RADAR | |
| 459 | SPACE VEHICLE ELECTRONIC TRACKING | |
| 461 | ACTIVE SONAR | |
| 462 | PASSIVE SONAR | W = 1.29 (WEIGHT OF GFE IN 462) |
| 463 | MULTIPLE MODE SONAR | W = 1.31 (WEIGHT OF GFE IN 463) |
| 464 | CLASSIFICATION SONAR | |
| 465 | BATHYTHERMOGRAPH | W = 1.67 (WEIGHT OF GFE IN 465) |
| 471 | ACTIVE ECM (INCL COMBINATION ACTIVE/PASSIVE) | |
| 472 | PASSIVE ECM | W = 1.54 (WEIGHT OF GFE IN 472) |
| 481 | GUN FIRE CONTROL SYSTEMS | W = 1.23 (WEIGHT OF GFE IN 481) |
| 482 | MISSILE FIRE CONTROL SYSTEMS | W = 1.20 (WEIGHT OF GFE IN 482) |
| 483 | UNDERWATER FIRE CONTROL SYSTEMS | W = 2.56 (WEIGHT OF GFE IN 483) |
| 484 | INTEGRATED FIRE CONTROL SYSTEMS | |
| 489 | WEAPON SYSTEMS SWITCHBOARDS | W = 1.65 (WEIGHT OF GFE IN 489) |

APPENDIX B
WEIGHT ALGORITHMS (Continued)

COST GROUP: 5A

| SWBS NO. | DESCRIPTION | WEIGHT ALGORITHMS |
|---|---|---|
| 511 | COMPARTMENT HEATING SYSTEM | W = 1.0142 (TOTAL SHIP VOLUME ($FT^3$)) x $10^{-5}$ |
| 512 | VENTILATION SYSTEM | W = 7.083 (TOTAL SHIP VOLUME ($FT^3$)) x $10^{-5}$ + 27.76 (IF SHIP HAS FAN COIL UNITS) |
| 513 | MACHINERY SPACE VENTILATION SYSTEM | W = 1.266 (TOTAL SHIP VOLUME ($FT^3$)) x $10^{-5}$ |
| 514 | AIR CONDITIONING SYSTEM | W = .0135 (MANNING) + .022 (TOTAL COMBAT SYSTEM HEAT DISSIPATION (KW)) + 10.0 (VOLUME OF ELECTRONIC SPACES ($FT^3$)) x $10^{-5}$ + 3.3 (VOLUME OF OTHER ARRANGEABLE SPACES* ($FT^3$)) x $10^{-5}$<br>* EXCLUDES MACHINERY SPACES, TANKS, AND ELECTRONIC SPACES |
| 516 | REFRIGERATION SYSTEM | W = 0.01212 (MANNING) |
| 517 | AUXILIARY BOILERS AND OTHER HEAT SOURCES | W = .056 (MANNING) |

## APPENDIX B
## WEIGHT ALGORITHMS (Continued)

COST GROUP: 5B

| SWBS NO. | DESCRIPTION | WEIGHT ALGORITHMS |
|---|---|---|
| 521 | FIREMAIN AND FLUSHING (SEA WATER) SYSTEM | W = 98.6 (MISSILE MAGAZINE VOLUME ($FT^3$)) x $10^{-5}$ + 45. (VOLUME OF OTHER MAGAZINES ($FT^3$)) x $10^{-5}$ + .01414 (TOTAL COMBAT SYSTEM HEAT DISSIPATION-KW) + 8.33 (MANNING) $10^{-3}$ + 4.55 (TOTAL SHIP VOLUME ($FT^3$)) x $10^{-5}$ + 1.4 (NUMBER OF SHAFTS) + 0.5 (IF AT LEAST 1 HELICOPTER IS CARRIED) |
| 522 | SPRINKLER SYSTEM | |
| 523 | WASHDOWN SYSTEM | W = 1.0 (SUPERSTRUCTURE VOLUME ($FT^3$)) x $10^{-5}$ |
| 524 | AUXILIARY SEA WATER SYSTEM | |
| 526 | SCUPPERS AND DECK DRAINS | W = .17 (TOTAL SHIP VOLUME ($FT^3$)) x $10^{-5}$ |
| 527 | FIREMAIN ACTUATED SERVICES - OTHER | |
| 528 | PLUMBING DRAINAGE | W = 2.0 (TOTAL SHIP VOLUME ($FT^3$)) x $10^{-5}$ |
| 529 | DRAINAGE AND BALLASTING SYSTEM | W = 3.182 (TOTAL SHIP VOLUME ($FT^3$)) x $10^{-5}$ |
| 531 | DISTILLING PLANT | W = .027 (MANNING) |
| 532 | COOLING WATER | W = .0409 (TOTAL COMBAT SYSTEM HEAT DISSIPATION TO DEMINERALIZED WATER (KW)) |
| 533 | POTABLE WATER | W = .039 (MANNING) |
| 534 | AUX. STEAM AND DRAINS WITHIN MACHINERY BOX | W = 1.3 (TOTAL SHIP VOLUME ($FT^3$)) x $10^{-5}$ |
| 535 | AUX. STEAM AND DRAINS OUTSIDE MACHINERY BOX | W = 2.5 (TOTAL SHIP VOLUME ($FT^3$)) x $10^{-5}$ |
| 536 | AUXILIARY FRESH WATER COOLING | |
| 541 | SHIP FUEL AND FUEL COMPENSATING SYSTEM | W = 26.0 + .018 (FUEL-TONS) |
| 542 | AVIATION AND GENERAL PURPOSE FUELS | W = 4.00 (IF ONE OR MORE HELICOPTERS ARE TO BE CARRIED OR REFUELED) |
| 543 | AVIATION AND GENERAL PURPOSE LUBRICATING OIL | |

APPENDIX B
WEIGHT ALGORITHMS (Continued)

COST GROUP: 5B (Continued)

| SWBS NO. | DESCRIPTION | WEIGHT ALGORITHMS |
|---|---|---|
| 544 | LIQUID CARGO | |
| 545 | TANK HEATING | |
| 549 | SPECIAL FUEL AND LUBRICANTS, HANDLING AND STOWAGE | |
| 551 | COMPRESSED AIR SYSTEMS | W = 2.4 (TOTAL SHIP VOLUME ($FT^3$)) x $10^{-5}$ WITHOUT PRAIRIE AIR + 1.5 (TOTAL SHIP VOLUME ($FT^3$)) x $10^{-5}$ FOR PRAIRIE AIR SYSTEM + 8.5 (NO. OF PROPULSION TURBINES ) + 1.9 (VOLUME OF WEAPON SPACES ($FT^3$)) x $10^{-4}$ |
| 552 | COMPRESSED GASES | |
| 553 | $O_2N_2$ SYSTEM | W = .25 (NUMBER OF COMBAT SYSTEMS REQUIRING $O_2$ OR $N_2$) |
| 554 | LP BLOW | |
| 555 | FIRE EXTINGUISHING SYSTEMS | W = 2.74 (TOTAL SHIP VOLUME ($FT^3$)) x $10^{-5}$ |
| 556 | HYDRAULIC FLUID SYSTEM | |
| 557 | LIQUID GASES, CARGO | |
| 558 | SPECIAL PIPING SYSTEMS | |
| 565 | TRIM AND HEEL SYSTEMS (SURFACE SHIPS) | |
| 593 | ENVIRONMENTAL POLLUTION CONTROL SYSTEMS | W = ..035 (MANNING) |
| 594 | SUBMARINE RESCUE, SALVAGE, AND SURVIVAL SYSTEMS | |

APPENDIX B
WEIGHT ALGORITHMS (Continued)

COST GROUP: 5C

| SWBS NO. | DESCRIPTION | WEIGHT ALGORITHMS |
|---|---|---|
| 561<br>562<br>568 | STEERING AND DIVING CONTROL SYSTEMS<br>RUDDER<br>MANEUVERING SYSTEMS | $W = 3.56 [(L)(H)]^2 \times 10^{-7} + 4.29 (L)(H) \times 10^{-3} + 2.52$ IF TWIN RUDDER<br>OR<br>$W = 4.456 (L)(H) \times 10^{-3} + 11.2$ IF SINGLE RUDDER<br><br>WHERE:<br>L = L.B.P.<br>H = DRAFT |

APPENDIX B
WEIGHT ALGORITHMS (Continued)

COST GROUP: 5D

| SWBS NO. | DESCRIPTION | WEIGHT ALGORITHMS |
|---|---|---|
| 571 | REPLENISHMENT-AT-SEA SYSTEMS | W = 1.7 (TOTAL SHIP VOLUME ($FT^3$)) x $10^{-5}$ + 3.0 |
| 572 | SHIP STORES AND EQUIPMENT HANDLING SYSTEMS | W = 1.48 (TOTAL SHIP VOLUME ($FT^3$)) x $10^{-5}$ |
| 573 | CARGO HANDLING SYSTEMS | |
| 574 | VERTICAL REPLENISHMENT SYSTEMS | |
| 581 | ANCHOR HANDLING AND STOWAGE SYSTEMS | W = 4.44 (TOTAL SHIP VOLUME ($FT^3$)) x $10^{-5}$ IF ONE ANCHOR<br>OR<br>W = 5.8 (TOTAL SHIP VOLUME ($FT^3$)) x $10^{-5}$ IF TWO ANCHORS |
| 582 | MOORING AND TOWING SYSTEMS | W = 1.16 (TOTAL SHIP VOLUME ($FT^3$)) x $10^{-5}$ + 4.8 |
| 583 | BOATS, BOAT HANDLING AND STOWAGE SYSTEMS | W = .03 (MANNING) IF 0 BOATS<br>OR<br>W = .03 (MANNING) + 5.8 IF 1 BOAT<br>OR<br>W = .03 (MANNING) + 14.5 IF 2 BOATS |
| 584 | MECHANICALLY OPERATED DOOR, GATE, RAMP, TURNTABLE SYSTEM | |
| 585 | ELEVATING AND RETRACTING GEAR | |
| 588 | AIRCRAFT HANDLING, SERVICING AND STOWAGE | W = 18.5 + NO. OF HELOS IF (RAST & BEAR TRAP)<br>OR<br>W = 10.0 + NO. OF HELOS IF HAULDOWN ONLY<br>OR<br>W = 1.0 + NO. OF HELOS OTHERWISE |
| 589 | MISCELLANEOUS MECHANICAL HANDLING SYSTEMS | |
| 592 | SWIMMER AND DIVER SUPPORT AND PROTECTION SYSTEMS | |
| 595 | TOWING, LAUNCHING AND HANDLING FOR UNDERWATER SYSTEMS | |
| 596 | HANDLING SYSTEMS FOR DIVER AND SUBMERSIBLE VEHICLES | |
| 597 | SALVAGE SUPPORT SYSTEMS | |

APPENDIX B
WEIGHT ALGORITHMS (Continued)

COST GROUP: 6A

| SWBS NO. | DESCRIPTION | WEIGHT ALGORITHMS |
|---|---|---|
| 605 | RODENT AND VERMIN PROOFING | |
| 611 | HULL FITTINGS | $W = 1.082$ (TOTAL SHIP VOLUME ($FT^3$)) x $10^{-5}$ |
| 612 | RAILS, STANCHIONS, AND LIFELINES | $W = .98$ (TOTAL SHIP VOLUME ($FT^3$)) x $10^{-5} - .43$<br>OR<br>$W = .897$ (TOTAL SHIP VOLUME ($FT^3$)) x $10^{-5} + 1.64$ IF HELO SAFETY NETS |
| 613 | RIGGING AND CANVAS | $W = 0.5$ LWL $\leq 450$<br>OR<br>$W = 1.0$ LWL $> 450$ |
| 625 | AIRPORTS, FIXED PORTLIGHTS, AND WINDOWS | $W = .07857$ (VOLUME OF SUPERSTRUCTURE ($FT^3$)) x $10^{-4}$ |

APPENDIX B
WEIGHT ALGORITHMS (Continued)

COST GROUP: 6B

| SWBS NO. | DESCRIPTION | WEIGHT ALGORITHMS |
|---|---|---|
| 621 | NON-STRUCTURAL BULKHEADS | W = 3.53 (TOTAL SHIP VOLUME ($FT^3$)) x $10^{-5}$ |
| 622 | FLOOR PLATES AND GRATINGS | W = 6.04 (TOTAL SHIP VOLUME ($FT^3$)) x $10^{-5}$ + 10.94 (IF EMPHASIS ON RELIABILITY AND MAINTENANCE) |
| 623 | LADDERS | W = .8866 (TOTAL SHIP VOLUME ($FT^3$)) x $10^{-5}$ |
| 624 | NON-STRUCTURAL CLOSURES | W = .794 (TOTAL SHIP VOLUME ($FT^3$)) x $10^{-5}$ |
| 637 | SHEATHING | W = .265 (TOTAL SHIP VOLUME ($FT^3$)) x $10^{-5}$ (EXCLUDES KEVLAR ARMOR WEIGHT) |

APPENDIX B

WEIGHT ALGORITHMS (Continued)

COST GROUP: 6C

| SWBS NO. | DESCRIPTION | WEIGHT ALGORITHMS |
|---|---|---|
| 602 | HULL DESIGNATING AND MARKING | |
| 603 | DRAFT MARKS | |
| 604 | LOCKS, KEYS, AND TAGS | |
| 631 | PAINTING | W = 5.0 (TOTAL SHIP VOLUME ($FT^3$)) x $10^{-5}$ |
| 632 | ZINC COATING | |
| 633 | CATHODIC PROTECTION | W = .172 (TOTAL SHIP VOLUME ($FT^3$)) x $10^{-5}$ |
| 634 | DECK COVERING | W = 2.83 (TOTAL SHIP VOLUME ($FT^3$)) x $10^{-5}$ |
| 635 | HULL INSULATION | <u>BASIC 635 WEIGHT:</u><br>W = 4.917 (TOTAL SHIP VOLUME ($FT^3$)) x $10^{-5}$<br><u>SHIP WITH DIESEL GEN/NO AUX BOILERS:</u><br>W = BASIC + 10.0 (TOTAL SHIP VOLUME ($FT^3$)) x $10^{-5}$<br><u>SHIP WITH PASSIVE FIRE ZONE PROTECTION:</u><br>W = BASIC + 7.5 (SUPERSTRUCTURE VOLUME − UPTAKE VOLUME ($FT^3$)) x $10^{-5}$ |
| 636 | HULL DAMPING | TYPE SONAR AND NOISE REQUIREMENTS DETERMINE WT. |
| 639 | RADIATION SHIELDING | |

APPENDIX B
WEIGHT ALGORITHMS (Continued)

COST GROUP: 6D

| SWBS NO. | DESCRIPTION | WEIGHT ALGORITHMS |
|---|---|---|
| 654 | UTILITY SPACES | |
| 655 | LAUNDRY SPACES | |
| 656 | TRASH DISPOSAL SPACES | |
| 664 | DAMAGE CONTROL STATIONS | W = 5.5 FOR $\Delta \leq$ 5,000 TONS<br>OR<br>W = 6.5 FOR $\Delta >$ 5,000 TONS |
| 665 | WORKSHOPS, LABS, TEST AREAS (INCLUDING PORTABLE TOOLS, EQUIPMENT) | W = 1.625 (TOTAL SHIP VOLUME ($FT^3$)) x $10^{-5}$ + 3.0 |
| 671 | LOCKERS AND SPECIAL STOWAGE | W = .0421 (MANNING) |
| 672 | STOREROOMS AND ISSUE ROOMS | W = .0667 (MANNING) IF NO VIDMAR CABINETS, OR<br>W = .1667 (MANNING) WITH VIDMAR CABINETS |

APPENDIX B
WEIGHT ALGORITHMS (Continued)

COST GROUP: 6E

| SWBS NO. | DESCRIPTION | WEIGHT ALGORITHMS |
|---|---|---|
| 638 | REFRIGERATED SPACES | W = .02376 (MANNING) |
| 641 | OFFICER BERTHING AND MESSING SPACES | W = 0.2 (MANNING) + 10.0 |
| 642 | NONCOMMISSIONED OFFICER BERTHING AND MESSING SPACES | (INCLUDES WEIGHT GROUPS 641, 642, 643, 651 - 656) |
| 643 | ENLISTED PERSONNEL BERTHING AND MESSING SPACES | |
| 644 | SANITARY SPACES AND FIXTURES | W = .077 (MANNING) - 12.48 |
| 645 | LEISURE AND COMMUNITY SPACES | W = .0183 (MANNING) - 2.75 |
| 651 | COMMISSARY SPACES | |
| 652 | MEDICAL SPACES | |
| 653 | DENTAL SPACES | |
| 661 | OFFICES | W = .02833 (MANNING) |
| 662 | MACHINERY CONTROL CENTERS FURNISHINGS | W = 1.0 FOR ONE GAS TURBINE OR W = 1.5 FOR TWO GAS TURBINES OR W = 2.0 FOR THREE GAS TURBINES |
| 663 | ELECTRONICS CONTROL CENTERS FURNISHINGS | W = 1.0 (TOTAL SHIP VOLUME ($FT^3$)) x $10^{-5}$ |

COST GROUP: 7

| SWBS NO. | DESCRIPTION | WEIGHT ALGORITHMS |
|---|---|---|
| 701 | GENERAL ARRANGEMENT - WEAPONRY SYSTEMS | |
| 711 | GUNS | |
| 712 | AMMUNITION HANDLING | |
| 713 | AMMUNITION STOWAGE | |
| 721 | LAUNCHING DEVICES (MISSILES AND ROCKETS) | |
| 722 | MISSILE, ROCKET, AND GUIDANCE CAPSULE HANDLING SYSTEM | |
| 723 | MISSILE AND ROCKET STOWAGE | |
| 724 | MISSILE HYDRAULICS | |
| 725 | MISSILE GAS | |
| 726 | MISSILE COMPENSATING | |
| 727 | MISSILE LAUNCHER CONTROL | |
| 728 | MISSILE HEATING, COOLING, TEMPERATURE CONTROL | |
| 729 | MISSILE MONITORING, TEST AND ALIGNMENT | |
| 731 | MINE LAUNCHING DEVICES | |
| 732 | MINE HANDLING | |
| 733 | MINE STOWAGE | |
| 741 | DEPTH CHARGE LAUNCHING DEVICES | |
| 742 | DEPTH CHARGE HANDLING | |
| 743 | DEPTH CHARGE STOWAGE | |
| 751 | TORPEDO TUBES | |
| 752 | TORPEDO HANDLING | |
| 753 | TORPEDO STOWAGE | |
| 754 | SUBMARINE TORPEDO EJECTION | |
| 761 | SMALL ARMS AND PYROTECHNIC LAUNCHING DEVICES | |
| 762 | SMALL ARMS AND PYROTECHNIC HANDLING | |
| 763 | SMALL ARMS AND PYROTECHNIC STOWAGE | |
| 770 | CARGO MUNITIONS | |
| 772 | CARGO MUNITIONS HANDLING | |
| 773 | CARGO MUNITIONS STOWAGE | |
| 782 | AIRCRAFT RELATED WEAPONS HANDLING | |

APPENDIX B
WEIGHT ALGORITHMS (Continued)

COST GROUP: 7

| SWBS NO. | DESCRIPTION | WEIGHT ALGORITHMS |
|---|---|---|
| 783 | AIRCRAFT RELATED WEAPONS STOWAGE | |
| 792 | SPECIAL WEAPONS HANDLING | |
| 793 | SPECIAL WEAPONS STOWAGE | |
| 797 | MISCELLANEOUS ORDNANCE SPACES | |

# APPENDIX C

# BSCI/SWBS COMPARISON

## Appendix C
## BSCI to SWBS Modifications

| | |
|---|---|
| Group 1A | 100 Change Cathodic Protection to 6C |
| Comment: | This involves about 2,000 man-hours for the electrical type system. Since the total man-hours in each group is rather large, the shift is not significant. The weight shift is negligible. |
| Group 1D | 122 Change Mechanical Operator System to 5D |
| Comment: | As this includes the power operation for special purpose doors only, the costs are already in 5D. |
| Group 2B | 203 Change Auxiliary S.W. Systems to 5B |
| Comment: | From a cost standpoint all auxiliary S.W. Systems are now in 5B. |
| Group 2C | 205 Change Stacks and Macks to 1D |
| Comment: | Splitting the inner and outer stack into different cost groups is not feasible or desired. They are generally built together as a single unit. |
| Group 4B | 405 Change Missiles Monitoring and Test to 7 |
| Comment: | This is a (high dollar) value item which, from a shipyard standpoint, should remain in the 405 Group. |
| Group 5A | 503 Change Refrigerated Space Insulation to 6C |
| Comment: | This is a separate BIW charge and, therefore, could be changed. However, from a cost standpoint it would seem preferable to leave it with the refrigerated spaces rather than with hull insulation. |
| Group 5B | 505 Change Plumbing Installations to 6E |
| Comment: | This primarily involves the fixtures only. Unfortunately, the BIW charge includes the associated drains, which could only be sorted out by guess work. |
| Group 5B | 514 Change High Pressure Steam Drain to 2D |
| Comment: | From a cost standpoint it does not make sense to separate this drain system from the others. Note this is only a very small system. |
| Group 6A | 600 Change Mooring and Towing Fitting to 5D |
| Comment: | This involves the mooring bitts and chocks that are now included with the other hull fittings. From the BIW standpoint, it would be better to leave them in 6A. |
| Group 6A | 601 Change Boats, Stowage and Handling to 5D |
| Comment: | This is a separate BIW charge and, therefore, could be changed. It might be questionable from a cost standpoint. |
| Group 6D | 608 Change Hull Repair Parts to 1D |
| Comment: | Change is insignificant. |
| Group 6D | 609 Change Environmental Pollution Control to 5B |
| Comment: | From a cost standpoint components such as garbage grinders and trash burners should not be mixed in with piping systems. |

# APPENDIX D

# SHIP SUBSYSTEM COST DRIVERS

APPENDIX D

| GROUP | PARAMETER | DD-931 | DDG-2 | CG-16 | CG-26 | FFG-1 | FFG-7 | DDG-40 | FF-1052 | DD-963 | DD-993 | CG-47 | DDGX |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1A | Mild Steel Hull | X | | | | X | X | | | | | | |
| | HTS Hull | X | X | X | X | | | | X | X | X | X | |
| | HY 80 Hull | | X | X | | | X | | | | | | |
| 1B | Steel Superstructure | | | | | | | | | | | | X |
| | Aluminum Superstructure | X | X | X | X | X | X | X | X | X | X | X | X |
| | Helicopter w/Hangar | | | | 1 | 1 | 2 | | X | X | X | X | |
| | Helicopter Landing Area Only | | | X | | | | | | | | | X |
| 1C | Shock Qualified Foundations | | | | X | X | X | | | X | X | X | X |
| | Non-Shock Qualified Foundations | X | X | X | X | | | X | X | | | | |
| | Steam (S) or Gas Turbine (T) | S | S | S | S | S | T | | | | | | |
| 1D | Ballistic Plating Yes (Y)/No (N) | N | N | Y | N | N | Y | N | N | | | | Y |
| | Sonar Size Small (S)/Large (L) | S | S | S | L | L | S | | L | L | L | L | L |

APPENDIX D (Continued)

| GROUP | PARAMETER | DD-931 | DDG-2 | CG-16 | CG-26 | FFG-4 | FFG-7 | DDG-40 | FF-1052 | DD-963 | DD-993 | CG-47 | DDGX |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2A | Single (S)/ Twin (T) Screw | T | T | T | T | S | S | T | S | T | T | T | T |
| | 1200 psig Steam | X | X | X | X | X | | X | X | | | | |
| | Geared Gas Turbine | | | | | | X | | | X | X | X | X |
| | Gas Turbine-Electric | | | | | | | | | | | | |
| | Diesel | | | | | | | | | | | | |
| | Integrated Electric | | | | | | | | | | | | X |
| | CODOG | | | | | | | | | | | | |
| | Auxiliary Propulsion Units | | | | | | 2 | | | | | | |
| 2B | Fixed Pitch Propellers | X | X | X | X | X | | X | X | | | | |
| | CRP Propellers | | | | | | X | | | X | X | X | X |
| 2C | Single Stack or Mack | | | | | X | X | | X | | | | X |
| | Multiple Stack or Mack | X | X | X | X | | | X | | X | X | X | |
| 2D | Steam, Non-Automated | | | | | X | | X | X | | | | |
| | Non-Steam, Automated | | | | | | X | | | X | X | X | X |
| | Non-Steam, Non-Automated | X | X | X | X | | | | | | | | |

APPENDIX D (Continued)

| GROUP | PARAMETER | DD-931 | DDG-2 | CG-16 | CG-26 | FFG-4 | FFG-7 | DDG-40 | FF-1052 | DD-963 | DD-993 | CG-47 | DDGX |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3A | Ship's Service Steam Turbo-Generator | 4 550-KW | 4 550-KW | 4 1000-KW | 4 1500-KW | 2 1000-KW | | X | X | | | | |
| | Diesel Generator | 2 100-KW | 2 100-KW | 1 300-KW | 1 300-KW | 2 500-KW | 4 1000-KW | | | | | | X |
| | Gas Turbine Generator | | | 1 300-KW | 1 300-KW | | | | | X | X | X | |
| | Integrated Electric | | | | | | | | | | | | X |
| | 400 Hz | MG Sets → X | X | X | X | X | Static X | X | X | X | X | X | X |
| 3B | Switchboards - Aluminum (A)/Steel (S) | A | S | A | A | A | S | | | | | | |
| 4A | Armored Cable | X | X | X | X | X | | X | | | | | |
| | Non-Armored Cable | | | | | | X | | | | | | |
| | Multiplexing | | | | | | | | | | | | |

APPENDIX D (Continued)

| GROUP | PARAMETER | DD-931 | DDG-2 | CG-16 | CG-26 | FFG-4 | FFG-7 | DDG-40 | FF-1052 | DD-963 | DD-993 | CG-47 | DDGX |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 5A | Steam (S)/Electric (E) Heat | S | S | S | S | S | E | S | S | E | E | E | E |
| | CPS = STOPS = CITADEL | | | | | | | | | | | | X |
| | | | | | | | | | | | | | |
| 5B | Missile Magazine Water Cooling | | | | | | X | X | | | X | X | X |
| | Prairie Masker | | | | | X | X | | | X | X | X | |
| | Clean Ballast | | | | | | X | | | X | X | X | X |
| | | | | | | | | | | | | | |
| 5C | Single (S)/Twin (T) Rudder | T | T | S | S | S | S | S | S | | | | |
| | Stabilizers | | | | | X | | | X | | | | |
| | NIXIE | | | | | | X | | | | | | |
| | | | | | | | | | | | | | |
| 5D | Helo Haul Down | | | | | | X | | | | | | |
| | Anchors | | | | 2 | 2 | 1 | | | | | | |
| | Refueling at Sea | | | | | | | | | | | | |

APPENDIX D (Continued)

| GROUP | PARAMETER | DD-931 | DDG-2 | CG-16 | CG-26 | FFG-4 | FFG-7 | DDG-40 | FF-1052 | DD-963 | DD-993 | CG-47 | DDGX |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 6A | Boats | 2 | 2 | 3 | 4 | 2 | 1 | | | | | | |
| 6B | No Sheathing | X | X | X | X | X | | X | X | | | | |
| | Normal Sheathing | | | | | | | | | | X | X | X |
| | Extensive Sheathing | | | | | | X | | | X | | | |
| 6C | Insul. Type - Structural (S)/Nonstructural (N) | N | N | N | N | N | S | | | S | S | S | S-Al N-St |
| | Sonar Sound Damping | | | | Full | Partial | | | | | | | |
| 6D | Vidmar Cabinets | | | | | | X | | | X | X | X | X |
| 6E | Pre-1956 Habitability Standards | X | X | | | | | | | | | | |
| | 1965 Habitability Standards | | | X | X | X | X | X | X | X | | X | |
| | 1979 Habitability Standards | | | | | | Met or Exceeded | | | | | | X |

# APPENDIX E

# DATA WORK SHEETS

TABLE E-1

INPUT DATA REQUIREMENTS TABLE
ONE-DIGIT LEVEL COST MODEL

| SHIP CHARACTERISTIC | COMMENTS | SHIP ________ VALUE |
|---|---|---|
| Group 1 Weight | Long Tons | |
| Group 3 Weight | Long Tons | |
| Group 4 Weight | Long Tons | |
| Group 5 Weight | Long Tons | |
| Group 6 Weight | Long Tons | |
| Group 7 Weight | (*See Group 7 discussion) Long Tons | |
| Cubic Number | LxBxD ÷ 100 | |
| Shaft Horsepower | SHP | |
| Kilowatts | KW | |
| Length x Beam | Square Feet | |
| Superstructure Material | Aluminum or Steel | |
| Propulsion Type and Number of Shafts | Steam, Gas turbine Single Shaft, etc. | |
| Generator Type | Steam, Diesel, etc. | |
| Habitability Standard | Year habitability standards designed to | |
| "MISSILE"/"NON-MISSILE" | Whether or not the vessel has missile magazine flooding requirements | |
| Level of Technology | Early or Current | |
| Heating System | Steam or Electric | |
| Months Construction | Approximately 30 months for an FFG-7 type vessel | |

NOTE: See the List of Abbreviations and Definitions for a detailed description of the variables used.

TABLE E-2
OUTPUT WORKSHEET
ONE-DIGIT LEVEL COST MODEL

| ALGORITHMS | | MATERIAL COSTS | LABOR MAN-HOURS |
|---|---|---|---|
| **GROUP 1 - HULL STRUCTURE** | | | |
| MATERIAL COSTS | | | |
| Cubic Number = ________ | Fig. 3.5 | | |
| OR | OR | | |
| Group 1 Weight = ________ | Fig. 3.6 | | |
| LABOR MAN-HOURS | | | |
| Cubic Number = ________ | Fig. 3.7 | - - - - - - - | - - - - - - - |
| OR | | | |
| Group 1 Weight = ________ | Fig. 3.8 | $ = | MH = |
| **GROUP 2 - PROPULSION PLANT** | | | |
| MATERIAL COSTS | | | |
| SHP = ________ | | | |
| Type of Propulsion = ________ | Fig. 3.19 | | |
| No. of Shafts = ________ | | | |
| LABOR MAN-HOURS | | - - - - - - - | - - - - - - - |
| SHP = ________ | | | |
| Type of Propulsion = ________ | Fig. 3.20 | $ = | MH = |
| **GROUP 3 - ELECTRICAL SYSTEM** | | | |
| MATERIAL COSTS | | | |
| KW = ________ | | | |
| Type of Generators = ________ | Fig. 3.29 | | |
| LABOR MAN-HOURS | | - - - - - - - | - - - - - - - |
| Group 3 Weight = ________ | | | |
| Type of Generators = ________ | Fig. 3.30 | $ = | MH = |
| **GROUP 4 - COMMAND AND CONTROL** | | | |
| MATERIAL COSTS | | | |
| Group 4 Weight = ________ | | | |
| Level of Technology = ________ | Fig. 3.35 | | |
| | | - - - - - - - | - - - - - - - |
| LABOR MAN-HOURS | | | |
| Group 4 Weight = ________ | Fig. 3.36 | $ = | MH = |

TABLE E-2
OUTPUT WORKSHEET (Continued)
ONE-DIGIT LEVEL COST MODEL

| ALGORITHMS | | MATERIAL COSTS | LABOR MANHOURS |
|---|---|---|---|
| **GROUP 5 - AUXILIARY SYSTEMS** | | | |
| MATERIAL COSTS | | | |
| Group 5 Weight = ______ | Fig. 3.41 | | |
| Heating System = ______ | | | |
| MISSILE = ______ | | | |
| LABOR MAN-HOURS | | | |
| Group 5 Weight = ______ | Fig. 3.42 | - - - - - - | - - - - - - |
| Heating System = ______ | | | |
| MISSILE = ______ | | $ = | MH = |
| **GROUP 6 - OUTFIT AND FURNISHINGS** | | | |
| MATERIAL COSTS | | | |
| Length x Beam = ______ | | | |
| Habitability Standard = ______ | Fig. 3.51 | | |
| OR | OR | | |
| Group 6 Weight = ______ | | | |
| Habitability Standard = ______ | Fig. 3.52 | | |
| LABOR MAN-HOURS | | - - - - - - | - - - - - - |
| Length x Beam = ______ | | | |
| Habitability Standard = ______ | Fig. 3.53 | $ = | MH = |
| **GROUP 7 - ARMAMENT** | | | |
| MATERIAL COSTS | | | |
| Group 7 Weight = ______ | | | |
| Level of Technology = ______ | Fig. 3.65 | | |
| | | - - - - - - | - - - - - - |
| LABOR MAN-HOURS | | | |
| Group 7 Weight = ______ | Fig. 3.66 | $ = | MH = |
| **GROUP 8 - DESIGN & ENGINEERING SERVICES** | | | |
| MATERIAL COSTS | | | |
| 1980 Cost = $ 540,000 | Table 3.9 | | |
| | | - - - - - - | - - - - - - |
| LABOR MAN-HOURS | | | |
| 1980 Hours = 307,000 MH | Table 3.9 | $ = | MH = |

OUTPUT WORKSHEET (Continued)
ONE-DIGIT LEVEL COST MODEL

| ALGORITHMS | | MATERIAL COSTS | LABOR MAN-HOURS |
|---|---|---|---|
| GROUP 9 - CONSTRUCTION SERVICES | | | |
| MATERIAL COSTS | | | |
| 1980 Cost = $ 45,500/month construction | Sec. 3.5.2 | | |
| LABOR MAN-HOURS | | | |
| 1980 Hours = 16,000 Hours/ Month Construction | Sec. 3.5.2 | $ = | MH = |

TABLE E-3
SUMMARY: MATERIAL COSTS & LABOR MAN-HOURS
ONE-DIGIT LEVEL COST MODEL

| COST GROUP | DESCRIPTION | MATERIAL COST | LABOR MAN-HOURS |
|---|---|---|---|
| 1 | HULL STRUCTURE | | |
| 2 | PROPULSION SYSTEM | | |
| 3 | ELECTRICAL SYSTEM | | |
| 4 | COMMUNICATIONS AND CONTROL | | |
| 5 | AUXILIARY SYSTEMS | | |
| 6 | OUTFIT AND FURNISHINGS | | |
| 7 | ARMAMENT | | |
| 8 | DESIGN & ENGINEERING SERVICES | | |
| 9 | CONSTRUCTION SERVICES | | |
| TOTAL MATERIAL COSTS AND MAN-HOURS | | | |
| | PRODUCTIVITY ADJUSTMENT (Labor Man-hours x Productivity Section 3.2.1) | | x |
| | LABOR RATE (\$/Man-Hour)[1] | | x |
| | TOTAL LABOR COST[2] | | \$ |
| | INFLATION FACTOR (Section 3.2.1)[3] | x | |
| | TOTAL MATERIAL COST[2] | \$ | |
| | + TOTAL LABOR COST | +\$ | |
| | TOTAL BASIC SHIP CONSTRUCTION COST[2] | \$ | |

1. The labor rate selected in \$/man-hour is the appropriate rate for the funding outlay profile.
2. The costs are program dollars.
3. The inflation factor is to adjust from 1980 dollars to the actual delivery year dollars.

TABLE E-4
INPUT DATA REQUIREMENTS TABLE
TWO-DIGIT LEVEL COST MODEL

| SHIP CHARACTERISTIC | COMMENTS | SHIP ______ VALUE |
|---|---|---|
| Group 1A Weight | Long Tons | |
| Group 1B Weight | Long Tons | |
| Group 1C Weight | Long Tons | |
| Group 1D Weight | Long Tons | |
| Group 2D Weight | Long Tons | |
| Group 3A Weight | Long Tons | |
| Group 3B Weight | Long Tons | |
| Group 4A Weight | Long Tons | |
| Group 4B Weight | Long Tons | |
| Group 5A Weight | Long Tons | |
| Group 5B Weight | Long Tons | |
| Group 5D Weight | Long Tons | |
| Group 6A Weight | Long Tons | |
| Group 6B Weight | Long Tons | |
| Group 6D Weight | Long Tons | |
| Group 6E Weight | Long Tons | |
| Group 7 Weight | Long Tons (*See Group 7 discussion) | |
| Cubic Number | LxBxD ÷ 100 | |
| Shaft Horsepower | SHP | |
| Kilowatts | KW | |

NOTE: See the List of Abbreviations and Defiitions for a detailed description of the variables used.

TABLE E-4
INPUT DATA REQUIREMENTS TABLE
TWO-DIGIT LEVEL COST MODEL (Continued)

| SHIP CHARACTERISTIC | COMMENTS | SHIP______ VALUE |
|---|---|---|
| LxH/100 | Square Feet | |
| LxB | Square Feet | |
| LxD | Square Feet | |
| Complement | | |
| Superstructure Material | Aluminum or Steel | |
| Type of Propulsion Plant | Steam, Gas Turbine, etc. | |
| Generator Type | Steam, Diesel, etc. | |
| Level of Technology | Early or Current | |
| Heating System | Steam or Electric | |
| "MISSILE"/"NON-MISSILE" | Whether or not the vessel has missile magazine flooding requirements | |
| Habitability Standards | Year habitability standards designed to | |
| Months Construction | Approximately 30 months for an FFG-7 type vessel | |

NOTE: See the List of Abbreviations and Definitions for a detailed description of the variables used.

TABLE E-5
OUTPUT WORKSHEET
TWO-DIGIT LEVEL COST MODEL

| ALGORITHMS | | MATERIAL COSTS | LABOR MAN-HOURS |
|---|---|---|---|
| **GROUP 1A - STRUCTURAL ENVELOPE** | | | |
| MATERIAL COSTS | | | |
| CUBIC NO. = ________ | Fig. 3.9 | | |
| OR | or | | |
| GROUP 1A WT = ________ | Fig. 3.10 | | |
| LABOR MAN-HOURS | | | |
| CUBIC NO. = ________ | Fig. 3.11 | | |
| OR | or | | |
| GROUP 1A WT = ________ | Fig. 3.12 | - - - - - - - | - - - - - - - |
| | | $ = | MH = |
| **GROUP 1B - SUPERSTRUCTURE** | | | |
| MATERIAL COSTS | | | |
| GROUP 1B WT = ________ | Fig. 3.13 | | |
| SUPERSTRUCTURE MTL = ____ | | | |
| LABOR MAN-HOURS | | | |
| GROUP 1B WT = ________ | Fig. 3.14 | | |
| SUPERSTRUCTURE MTL = ____ | | | |
| (A 2% labor savings may be used if: (1) material = aluminum, and (2) it is machine cut) | | - - - - - - - | - - - - - - - |
| 1B Man-hours = Man-hours - (.02 x Man-hours) | | $ = | MH = |
| **GROUP 1C - FOUNDATIONS** | | | |
| MATERIAL COSTS | | | |
| GROUP 1C WT = ________ | | | |
| TYPE OF PROPULSION PLANT = ________ | Fig. 3.15 | | |
| LABOR MAN-HOURS | | | |
| GROUP 1C WT = ________ | | | |
| TYPE OF PROPULSION PLANT = ________ | Fig. 3.16 | - - - - - - - | - - - - - - - |
| | | $ = | MH = |
| **GROUP 1D - STRUCTURAL ATTACHMENTS** | | | |
| MATERIAL COSTS | | | |
| GROUP 1D WT = ________ | Fig. 3.17 | | |
| LABOR MAN-HOURS | | | |
| GROUP 1D WT = ________ | Fig. 3.18 | - - - - - - - | - - - - - - - |
| | | $ = | MH = |

TABLE E-5
OUTPUT WORKSHEET (Continued)
TWO-DIGIT LEVEL COST MODEL

| ALGORITHMS | | MATERIAL COSTS | LABOR MAN-HOURS |
|---|---|---|---|
| **GROUP 2A - PROPULSION ENERGY SYSTEM** | | | |
| MATERIAL COSTS<br>SHP = ________<br>Type of Propulsion Plant = ________ | Fig. 3.21 | | |
| LABOR MAN-HOURS<br>SHP = ________<br>Type of Propulsion Plant = ________ | Fig. 3.22 | $ = | MH = |
| **GROUP 2B - PROPULSION TRAIN** | | | |
| MATERIAL COSTS<br>SHP = ________ | Fig. 3.23 | | |
| LABOR MAN-HOURS<br>SHP = ________ | Fig. 3.24 | $ = | MH = |
| **GROUP 2C - PROPULSION GASES** | | | |
| MATERIAL COSTS<br>SHP = ________<br>Type of Propulsion Plant = ________ | Fig. 3.25 | | |
| LABOR MAN-HOURS<br>SHP = ________ | Fig. 3.26 | $ = | MH = |
| **GROUP 2D - PROPULSION SERVICE** | | | |
| MATERIAL COSTS<br>SHP = ________<br>Type of Propulsion Plant = ________ | Fig. 3.27 | | |
| LABOR MAN-HOURS<br>GROUP 2D WT = ________ | Fig. 3.28 | $ = | MH = |

TABLE E-5
OUTPUT WORKSHEET (Continued)
TWO-DIGIT LEVEL COST MODEL

| ALGORITHMS | | MATERIAL COSTS | LABOR MAN-HOURS |
|---|---|---|---|
| GROUP 3A - ELECTRICAL POWER GENERATION | | | |
| MATERIAL COSTS | | | |
| KW = ______ | | | |
| Generator Type = ______ | Fig. 3.31 | | |
| LABOR MAN-HOURS | | | |
| GROUP 3A WT = ______ | Fig. 3.32 | $ = | MH = |
| GROUP 3B - ELECTRICAL POWER DISTRIBUTION | | | |
| MATERIAL COSTS | | | |
| GROUP 3B WT = ______ | Fig. 3.33 | | |
| LABOR MAN-HOURS | | | |
| GROUP 3B WT = ______ | Fig. 3.34 | $ = | MH = |
| GROUP 4A - VEHICLE COMMAND | | | |
| MATERIAL COSTS | | | |
| GROUP 4A WT = ______ | | | |
| Level of Technology = ______ | Fig. 3.37 | | |
| LABOR MAN-HOURS | | | |
| GROUP 4A WT = ______ | Fig. 3.38 | $ = | MH = |
| GROUP 4B - WEAPONS COMMAND | | | |
| MATERIAL COSTS | | | |
| GROUP 4B WT = ______ | | | |
| Level of Technology = ______ | Fig. 3.39 | | |
| LABOR MAN-HOURS | | | |
| GROUP 4B WT = ______ | Fig. 3.40 | $ = | MH = |

TABLE E-5
OUTPUT WORKSHEET (Continued)
TWO-DIGIT LEVEL COST MODEL

| ALGORITHMS | | MATERIAL COSTS | LABOR MAN-HOURS |
|---|---|---|---|
| GROUP 5A - ENVIRONMENT | | | |
| MATERIAL COSTS | | | |
| GROUP 5A WT = ______ | | | |
| HEATING SYSTEM = ______ | Fig. 3.43 | | |
| LABOR MAN-HOURS | | | |
| GROUP 5A WT = ______ | | | |
| HEATING SYSTEM = ______ | Fig. 3.44 | $ = | MH = |
| GROUP 5B - FLUID SYSTEMS | | | |
| MATERIAL COSTS | | | |
| GROUP 5B WT = ______ | | | |
| MISSILE = ______ | Fig. 3.45 | | |
| LABOR MAN-HOURS | | | |
| GROUP 5B WT = ______ | | | |
| MISSILE = ______ | Fig. 3.46 | $ = | MH = |
| GROUP 5C - MANEUVERING | | | |
| MATERIAL COSTS | | | |
| LxH/100 = ______ | Fig. 3.47 | | |
| LABOR MAN-HOURS | | | |
| LxH/100 = ______ | Fig. 3.48 | $ = | MH = |
| GROUP 5D - HANDLING | | | |
| MATERIAL COSTS | | | |
| GROUP 5D WT = ______ | Fig. 3.49 | | |
| LABOR MAN-HOURS | | | |
| GROUP 5D WT = ______ | Fig. 3.50 | $ = | MH = |

TABLE E-5
OUTPUT WORKSHEET (Continued)
TWO-DIGIT LEVEL COST MODEL

| ALGORITHMS | | MATERIAL COSTS | LABOR MAN-HOURS |
|---|---|---|---|
| <u>GROUP 6A - HULL FITTINGS</u> | | | |
| MATERIAL COSTS | | | |
| LxB = ________ | | | |
| LEVEL OF TECHNOLOGY = ________ | Fig. 3.54 | | |
| LABOR MAN-HOURS | | | |
| GROUP 6A WT = ________ | Fig. 3.55 | $ = | MH = |
| <u>GROUP 6B - NON-STRUCTURAL SUBDIVISIONS</u> | | | |
| MATERIAL COSTS | | | |
| GROUP 6B WT = ________ | Fig. 3.56 | | |
| HABITABILITY STANDARDS = ________ | | | |
| OR | OR | | |
| LxD = ________ | | | |
| HABITABILITY STANDARDS = ________ | Fig. 3.57 | | |
| LABOR MAN-HOURS | | | |
| GROUP 6B WT = ________ | Fig. 3.58 | $ = | MH = |
| <u>GROUP 6C - PRESERVATION</u> | | | |
| MATERIAL COSTS | | | |
| LxB = ________ | | | |
| LEVEL OF TECHNOLOGY = ________ | Fig. 3.59 | | |
| LABOR MAN-HOURS | | | |
| LxB = ________ | Fig. 3.60 | $ = | MH = |
| <u>GROUP 6D - FACILITIES</u> | | | |
| MATERIAL COSTS | | | |
| COMPLEMENT = ________ | | | |
| HABITABILITY STANDARDS = ________ | Fig. 3.61 | | |
| LABOR MAN-HOURS | | | |
| GROUP 6D WT = ________ | | | |
| HABITABILITY STANDARDS = ________ | Fig. 3.62 | $ = | MH = |

TABLE E-5
OUTPUT WORKSHEET (Continued)
TWO-DIGIT LEVEL COST MODEL

| ALGORITHMS | | MATERIAL COSTS | LABOR MAN-HOURS |
|---|---|---|---|
| **GROUP 6E - HABITABILITY** | | | |
| MATERIAL COSTS | | | |
| GROUP 6E WT = ________ | | | |
| HABITABILITY STANDARDS = ________ | Fig. 3.63 | | |
| LABOR MAN-HOURS | | | |
| GROUP 6E WT = ________ | Fig. 3.64 | $ = | MH = |
| **GROUP 7 - ARMAMENT** | | | |
| MATERIAL COSTS | | | |
| GROUP 7 WT = ________ | | | |
| LEVEL OF TECHNOLOGY = ________ | Fig. 3.65 | | |
| LABOR MAN-HOURS | | | |
| GROUP 7 WT = ________ | Fig. 3.66 | $ = | MH = |
| **GROUP 8 - DESIGN AND ENGINEERING SERVICES** | | | |
| MATERIAL COSTS | | | |
| 1980 COST = $ ~~540,000~~ 995,000 | Table 3.9 | | |
| LABOR MAN-HOURS | | | |
| 1980 HOURS = ~~307,000~~ 801,000 MH | Table 3.9 | $ = | MH = |
| **GROUP 9 - CONSTRUCTION SERVICES** | | | |
| MATERIAL COSTS | | | |
| 1980 COST = $ 45,500/MONTH CONSTRUCTION | Sec. 3.5.2 | | |
| LABOR MAN-HOURS | | | |
| 1980 HOURS = 16,000/MONTH CONSTRUCTION | Sec. 3.5.2 | $ = | MH = |

TABLE E-6
SUMMARY: MATERIAL COSTS AND LABOR MAN-HOURS
TWO-DIGIT LEVEL COST MODEL

| COST GROUP | DESCRIPTION | MATERIAL COSTS | LABOR MAN-HOURS |
|---|---|---|---|
| 1A | STRUCTURAL ENVELOPE/SUBDIVISIONS | | |
| 1B | SUPERSTRUCTURE | | |
| 1C | FOUNDATIONS | | |
| 1D | STRUCTURAL ATTACHMENTS | | |
| 2A | PROPULSION ENERGY SYSTEM | | |
| 2B | PROPULSION TRAIN | | |
| 2C | PROPULSION GASES | | |
| 2D | PROPULSION SERVICE | | |
| 3A | ELECTRICAL POWER GENERATION | | |
| 3B | ELECTRICAL POWER DISTRIBUTION | | |
| 4A | VEHICLE COMMAND | | |
| 4B | WEAPONS COMMAND | | |
| 5A | ENVIRONMENT | | |
| 5B | FLUID SYSTEMS | | |
| 5C | MANEUVERING | | |
| 5D | HANDLING | | |
| 6A | HULL FITTINGS | | |
| 6B | NON-STRUCTURAL SUBDIVISIONS | | |
| 6C | PRESERVATION | | |
| 6D | FACILITIES | | |
| 6E | HABITABILITY | | |
| 7 | ARMAMENT | | |
| SUBTOTAL | MATERIAL COST AND MAN-HOURS | | |

TABLE E-6
SUMMARY: MATERIAL COSTS AND LABOR MAN-HOURS
TWO-DIGIT LEVEL COST MODEL (Continued)

| COST GROUP | DESCRIPTION | MATERIAL COSTS | LABOR MAN-HOURS |
|---|---|---|---|
| SUBTOTAL MATERIAL COSTS AND MAN-HOURS | | | |
| 8 | DESIGN AND ENGINEERING SERVICES | | |
| 9 | CONSTRUCTION SERVICES | | |
| TOTAL MATERIAL COSTS AND MAN-HOURS | | | |
| PRODUCTIVITY ADJUSTMENT (Labor Man-Hours x Productivity Section 3.2.1) | | | x |
| LABOR RATE ($/Man-Hour)[1] | | | x |
| TOTAL LABOR COST[2] | | | $ |
| INFLATION FACTOR (Section 3.2.1)[3] | | x | |
| TOTAL MATERIAL COST[2] | | $ | |
| + TOTAL LABOR COST | | +$ | |
| TOTAL BASIC SHIP CONSTRUCTION COST[2] | | $ | |

1. The labor rate selected in $/man-hour is the appropriate rate for the funding outlay profile.
2. The costs are program dollars.
3. The inflation factor is to adjust from 1980 dollars to the actual delivery year dollars.

# APPENDIX F

## UNUSED PLOTS

(Under Separate Cover)